THE

SOUTH AFRICAN JOURNAL OF SCIENCE

VOLUME XXXVI

BEING THE

REPORT

OF THE

THIRTY-SEVENTH ANNUAL MEETING

OF THE

SOUTH AFRICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

EAST LONDON
1939
3 JULY to 8 JULY

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1939

Form of Application for Membership

To the Assistant General Secretaries,

South African Association
for the Advancement of Science,
P.O. Box 6894, Johannesburg.

I desire to become *.............................. member of the South African Association for the Advancement of Science, and for this purpose I enclose a cheque for £..........................†

1. Name in full ... .
2. Academic Degrees or Diplomas, Fellowships of Learned Societies, etc., held (if any) ... .
   (Note.—Academic qualifications, etc., are not indispensable.)
3. Profession or Occupation
4. Full Postal Address .... .
5. Signature ....
6. Proposed by ‡ ....

Date ....

* Please state whether "Ordinary Member," "Life Member," or "Associate Member." Subscriptions are as follows: Life Members, £15; after ten consecutive years as an Ordinary Member, £7 10s. Ordinary Members, £1 10s. per annum. Associate Members, £1, for period of the Annual Session only. Student Members (not exceeding 23 years), 10s. 6d. for period of Annual Session only. (Associate and Student Members are not entitled to receive the Journal of the Association.)

Certain back numbers of the Journal are now obtainable from the Hon. Librarian, University, Milner Park, Johannesburg, at a reduced rate.

Candidates resident in the Witwatersrand (Randfontein to Springs) should add the sum of £1 1s. for membership of the Associated Scientific and Technical Societies of South Africa.

† Cheques, etc., should be crossed and made payable to the Assistant General Secretary, South African Association for the Advancement of Science, and 6d. should be added to country cheques to cover exchange.

‡ In this respect the Assistant General Secretaries will be prepared to assist applicants.

THE

SOUTH AFRICAN JOURNAL OF SCIENCE

BEING THE REPORT OF THE

SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

(1939, EAST LONDON)

Vol. XXXVI — JULY, 1939. — Vol XXXVI

EDITORIAL NOTE.

Once again the contributors to the JOURNAL have shown a commendable spirit of co-operation in the way in which they have assisted me in controlling the volume of material presented for publication. They have been prepared to reduce the length of papers, to prepare abstracts, and to record their contributions in title only. It thus has been possible to produce a JOURNAL of reasonable length—an absolute essential in these days of straitened finances.

The Council authorised the publication of the Symposium addresses in the belief that information of general national importance was contained in these, and that it was the duty of the Association to place permanently on record this information.

Capt H. A. G. Jeffreys, O.B.E., for many years Assistant General Secretary to the Association, retired while the current number of the JOURNAL was in the preliminary stages; I desire to express my appreciation of the services Capt. Jeffreys rendered in business matters connected with the JOURNAL since I assumed office.

To Mr. V. L. Bosazza, Minerals Research Laboratory, Johannesburg, I am indebted for kindly assistance in several important details.

Once again Mr. S. B. Asher has assisted me by preparing the Index.

The Council keenly appreciates the monetary assistance kindly rendered by certain contributors.

John Phillips

Hon. Editor of Publications.

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PROCEEDINGS OF THE THIRTY-SEVENTH ANNUAL GENERAL MEETING OF MEMBERS, HELD AT THE SELBORNE COLLEGE, EAST LONDON, ON FRIDAY, 7TH JULY, 1939, AT 10.30 A.M.

PRESENT: Professor G. H. Stanley (President), in the Chair, Mr. J. T. Allan, Mr. F. J. S. Anders, Miss E. E. A. Archibald, Mr. S. B. Asher, Professor A. W. Bayer, Mrs. H. Boehmke, Dr. M. Boehmke, Mr. N. R. Bryant, Mrs. M. H. Bush, Dr. S. F. Bush, Mr. J. E. Colepeper, Miss M. Courtney-Latimer, Mr R. Craib, Professor R. A. Dart, Mrs. M. E. Dart, Professor C. G. S. de Villiers, Mr. B. H. Dodd, Mr. H. H. Dodds, Miss I. A. E. Rosenberg-Drege, Dr. A. L. du Toit, Miss B. S. Fisher, Dr. F. W. Fox, Miss J. Freeland, Miss D. M. Gemmell, Mrs. M. G. Gemmell, Mr. J. H. Gilchrist, Professor A. P. Goosens, Mr. T. D. Hall, Dr. Miss M. Henrici, Miss J. Henshel, Mr. G. Ingham, Dr. E. Jokl, Dr. C. F. Juritz (Honorary General Secretary), Miss I. Juritz, Professor P. R. Kirby, Hon. Dr. F. E. T. Krause, Dr. Miss M. S. J. Ledeboer, Mr. A. J. Limebeer, Dr. W. J. Lutjeharms, Miss A. Lyle, Dr. R. H. Marloth, Mr. H. B. Maufe, Miss M. R. McEwan, Mrs. H. M. McKay, Dr. Miss M. G. Mes, Professor E. D. Mountain, Miss J. M. Murray, Dr. J. Nanni, Professor John Orr, Mrs. H. Paine, Professor H. H. Paine, Dr. E. P. Phillips, Professor John Phillips, Mr. J. H. Power, Mr. J. T. Pringle, Dr. J. I. Quin, Mr. J. F. Schofield, Mr. J. D. Scott, Dr. B. Segal, Mr. F. J. Smith, Professor N. J. G. Smith, Miss E. L. Stephens, Dr. Miss G. Theiler, Dr. E. C. N. van Hoepen, Dr. L. H. Wells, Miss E. E. Wijers, Dr. H. E. Wood (Honorary General Secretary), and H. A. G. Jeffreys (Assistant General Secretary).

MINUTES.—The Minutes of the Thirty-sixth Annual General Meeting, held at Pietermaritzburg, on the 8th July, 1938, and printed on pages iii to vi of the Report of the Pietermaritzburg Session (Volume XXXV of the JOURNAL), were confirmed.

ANNUAL REPORT OF COUNCIL.—The President expressed his thanks to members of Council for the efficient way in which they had supported him during the year. The Report for the year 1938-1939 was read by Dr. H. E. Wood and adopted. (See pages .... of this issue).

REPORT OF THE HONORARY GENERAL TREASURER AND STATEMENT OF ACCOUNTS.—The Honorary General Treasurer's Report and Statement of Accounts for the year ended 31st May, 1939, having been duly suspended on the notice board at the Selborne College, were taken as read and adopted. (See pages .... of this issue).

ELECTION OF OFFICERS FOR 1939-1940.—The following were elected:—

President: Professor C. G. S. de Villiers.

Vice-Presidents: Professor Hugh Clark.
Mr. Jas. Gray.
Professor M. M. Rindl.
Col. J. G. Rose.

Hon. General Secretaries: Dr. C. F. Juritz and Dr. H. E. Wood.

Hon. General Treasurer: Jas. Gray.

Hon. Editor of Publications: Professor John Phillips.

Hon. Librarian: Mr. P. Freer.

COUNCIL MEMBERS.—The following were elected:—

I. TRANSVAAL.—Mr. J. T. Allan Mr. S. B. Asher, Mr. R. Craib, Professor R. A. Dart, Dr. A. L. du Toit, Dr. A. Galloway, Dr. J.

Gillman, Mr. T. D. Hall, Dr. E. J. Hamlin, Professor P. R. Kirby, Mr. A. J. Limebeer, Professor C. van Riet Lowe, Professor I. D. MacCrone, Professor L. F. Maingard, Professor John Orr, Professor H. H. Paine, Mr. F. R. Paver, Miss H. P. Pollak, Dr. J. B. Robertson, Professor B. F. J. Schonland, Dr. B. Segal, Dr. R. Broom, Professor P. J. du Toit, Dr. R. J. Ortlepp. Mr. E. Parish, Dr. E. P. Phillips, Dr. A. Pijper, Dr. E. M. Robinson, Professor A. P. Goosens, Dr. R. H. Marloth.

II. Cape of Good Hope Province.—Dr. L. Boonstra, Col. C. Graham Botha, Dr. A. J. Hesse, Mr. G. W. Lyon, Dr. B. de C. Marchand, Dr. S. H. Skaife, Mr. F. J. S. Anders, Mr. G. O. Neser, Professor L. Verwoerd, Mr. J. H. Power, Professor N. J. Smith, Dr. M. Boehmke, Dr. P. W. Laidler.

III. Orange Free State.—Dr. W. J. Lutjeharms, Dr. E. C. van Hoepen.

IV. Natal.—Professor A. W. Bayer Dr. S. F. Bush, Mr. E. C. Chubb, Mr. H. H. Dodds, Dr. John Fisher, Mr. J. F. Schofield.

V. Southern Rhodesia.—Rev. Neville Jones, Mr. H. B. Maufe.

Annual Meeting, 1940.—Two invitations had been received, viz., from the Municipalities of Cape Town and Salisbury. On being put to the meeting the invitation for the Association to hold its Annual Session in Salisbury in 1940, was accepted unanimously.

Report of Allan Committee.—This report was discussed at considerable length and adopted.

Organisation of Annual Meetings.—This pamphlet, which had been suspended on the notice board, was adopted.

Symposia.—The following resolution, proposed by Professor A. W. Bayer and seconded by Dr. J. I. Quin, was referred to Council:—" This Meeting requests the Council to consider for the next Meeting of the Association a Symposium on the necessity for the better organisation of scientific work and workers in South Afrcia."

Fort Murray.—The following resolution, proposed by Professor P. R. Kirby and seconded by Mr. J. F. Schofield, was carried unanimously:—" This Association urges the Historical Monuments Commission to take immediate steps to preserve the remains of Fort Murray, declared by it as a National Historical Monument, as, in its present condition and owing to recent gales, it is threatened with disintegration."

East London Aquarium.—The following resolution, presented by Section D, was carried unanimously:—" Section D of this Association desires to express its admiration for the work accomplished by Dr. J. Nanni at the East London Aquarium, and would recommend to the Municipality of East London that Dr. Nanni be given further financial support with a view to extending the activities of the Aquarium in a scientific as well as a popular direction."

Nutritional Council.—Dr. J. I. Quin moved the following resolution which was referred to Council:—" This Association urges the appointment in South Africa of a Nutritional Council constituted along the lines suggested by the mixed Committee of the League of Nations in 1936 and since adopted with considerable success by over twenty other countries."

Votes of Thanks.—On the motion of Professor John Orr it was agreed unanimously that the thanks of the Association be accorded to the following:—

To His Worship the Mayor (Councillor Col. Greville Lewis), the Mayoress, and members of the Local and Reception Committees, for the excellent arrangements for the meeting.

To the members of the Ladie's Committee for kindly providing morning and afternoon teas.

To the Principal of the Selborne College (Mr. G. F. Floyd), the East London School Board, and the Selborne College Committee, for the use of the College buildings.

To the ladies and gentlemen who kindly provided transport for excursions.

For hospitality on excursions:—

To Messrs. Wilson for the invitation to visit their Sweet Factory.

To Mr. G. G. Smith for the visit to his collection of succulent plants.

To the Rev. Kinnerley at Mt. Coke and His Worship the Mayor of Kingwilliamstown.

To the Curator of the Aquarium (Dr. J. Nanni), for his demonstration at the Aquarium and to Mrs. Nanni.

To the Director of the East London Museum.

To Major Kreft, Principal of the de Waal School, for the visit to the de Waal Nursery School class.

To. Mr. B. H. Dodd, Acting Chairman of the Local Committee.

To the Acting Manager of the Municipal Transport, Mr. Johnstone.

To Mr. Dersley for making the necessary arrangements for the cine.

To the Press for their services n reporting papers read at the meeting.

For the privileges of honorary membership during the Session:— To the East London Club to the East Bank Golf Course; to the West Bank Golf Course.

To Dr. P. W. Laidler (Hon Secretary of the Local Committee) for his valuable services in connection with the arrangements for the meeting, and to Mrs. Laidler for her very efficient assistance, which has contributed so greatly to the very pronounced success of our visit to East London.

REPORT OF COUNCIL FOR THE YEAR ENDED 30TH JUNE, 1939.

1. OBITUARY.—Your Council has to report with deep regret the deaths of the following members:—Mr. H. Ashton, Professor J. W. Bews (President of the Association, 1931, President of Section C, 1921, South Africa Medallist, 1932), Dr. F. V. Engelenburg, Professor H. J. S. Heather, Mr. W. Mauss, Professor H. Clark Powell, Mr. D. W. Rossiter, Dr. T. R. Sim (South Africa Medallist, 1916), Dr. J. S. P. Stewart.

2. MEMBERSHIP.—Since the last Report 49 new members have joined the Association, nine have died, and 21 have resigned. The net increase, therefore, has been 19. The following comparative table, as from the 1st July last year, shows the geographical distribution of membership:—

	1938.	1939.
Transvaal	369	374
Cape of Good Hope Province	216	213
Natal	86	97
Orange Free State	33	38
Southern and Northern Rhodesia	14	14
South West Africa	3	4
Moçambique	6	6
Abroad	24	24
	751	770

3. THE JOURNAL.—Volume XXXV of the *South African Journal of Science*, comprising the Report of the Pietermaritzburg Meeting, consisted of 514 pages, 14 plates and numerous text figures. It was published in June, 1939.

4. THE SOUTH AFRICA MEDAL AND GRANT.—On the recommendation of the South Africa Medal Committee, consisting of Dr. H. E. Wood (Chairman), Professor C. G. S. de Villiers, Dr. A. L. du Toit, Professor P. J. du Toit, Dr. J. S. Henkel, Dr. John Hewitt, Professor P. R. Kirby, Professor I. D. MacCrone, Professor L. F. Maingard, Dr. E. P. Phillips, Professor M. M. Rindl, Professor B. F. J. Schonland, your Council has awarded the South Africa Medal, together with grant of £56 15s. to Professor R. A. Dart. The Secretary of the British Association has been notified of the award.

5. THE BRITISH ASSOCIATION MEDAL.—The British Association has awarded the British Association Medal for 1938 to Miss Jean Margaret Murray, formerly of the Botanical Department, University of the Witwatersrand, Johannesburg, and now a member of the Staff of the Division of Plant Industry, Pretoria, for her paper entitled "An Investigation of the Inter-Relationship of Vegetation, Soils and Termites."

6. DONATIONS.—The thanks of the Association are due to the Honourable the Minister of the Interior, Education and Public Health

for a grant of £250 and to His Worship the Mayor and the City Council of Johannesburg for a grant of £100 towards the expenses of the publication of the JOURNAL.

7. QUARTERLY BULLETINS.—Three Bulletins have been issued during the year 1938-39, viz.:—Bulletin No. 1 in January, 1939, Bulletin No. 2 in May, 1939, and Bulletin No. 3 in June, 1939.

8 REPORT OF "ALLAN" COMMITTEE.—A Committee was formed on the 23rd September, 1938, to consider matters arising out of a motion by Mr. J. T. Allan affecting the JOURNAL, the conduct of Annual Meetings, increase in membership and the activities and progress of the Association in general. For brevity of title this Committee is referred to as the "Allan" Committee. The Committee has met on four occasions and presents its report to the Annual General Meeting. This report recommends:—

(a) that the JOURNAL should continue to be published as at present annually;

(b) that the publication of the Quarterly Bulletins should be continued;

(c) that the holding of quarterly meetings, partaking of the nature of symposia rather than for the presentation of original papers, at the various local centres, with a view to stimulating greater interest in the Association should be considered;

(d) that the policy of selecting some special subject for general discussion at the Annual Session should be continued and that it might be extended to the individual Sections of the Association;

(e) that steps should be taken to arrange that Sections of the Association, taken in rotation, be organised and assisted financially for special representation at an Annual Session;

(f) that the question of providing travelling grants for advanced students and others who would not otherwise attend the Meetings, should be considered.

9. ORGANISATION OF ANNUAL MEETINGS.—Your Council has prepared a pamphlet dealing with the Organisation of Annual Sessions for the information of the local authorities who may invite the Association to hold its Annual Session in their locality. This pamphlet details the normal procedure which has been found most suitable in the preliminary preparation for an Annual Session and the practical arrangements for the holding of the Session. The adoption of this pamphlet by the Annual General Meeting will necessitate the alteration of certain clauses in the Constitution and By-Laws of the Association, e.g. with reference to the formation of a Local Committee.

10. SOCIAL AND INTERNATIONAL RELATIONS OF SCIENCE.—A Committee was appointed to draw up a reply to a general questionnaire received from the Committee on Science in its Social Relations of the International Council of Scientific Unions. The report formulated by this Committee has been forwarded to the Secretary of the International Council of Scientific Unions at Delft.

11. THE NEW COUNCIL.—On the basis of membership provided in the Constitution, Section 20, the number of members of Council

assigned for the representation of each Centre for the year 1939/40 should be distributed as follows:—

Transvaal—	
Witwatersrand	20
Pretoria	7
Outside	1
Cape of Good Hope Province—	
Cape Peninsula	5
Stellenbosch	3
East London and Port Elizabeth ...	1
Grahamstown, Kingwilliamstown and District	1
Kimberley	1
Oudtshoorn	1
Outside	1
Natal—	
Pietermaritzburg and Durban	5
Outside	1
Orange Free State—	
Bloemfontein	2
Southern Rhodesia	2
Moçambique	1
Total	52

The Council wishes to place on record its appreciation of the valuable services and effective assistance rendered throughout the year by the Assistant General Secretary, Mr. H. A. G. Jeffreys, O.B.E.

REPORT OF THE HONORARY GENERAL TREASURER FOR THE YEAR ENDED 31st MAY, 1939.

Notwithstanding the efforts of the Editor and the Editorial Committee, the cost of printing the JOURNAL is £200 more than last year and under these circumstances, a deficit of £98 13s. can be regarded as reasonably satisfactory.

The revenue from subscriptions is slightly lower than last year notwithstanding a slight increase in membership.

The continued generosity of the City Council of Johannesburg in donating £100 is greatly appreciated.

JAS. GRAY,
Honorary General Treasurer.

THE SOU AFRICAN ASSOCIATION FOR THE ADVANC ENT OF SCI CE.

BALANCE S AT MAY, 1939.

LIABILITIES.

	£ s. d.			£	s.	d.
Sundry Creditors—						
General Accounts	£917	1	4			
Witwatersrand Local Centre ...	179	0	1			
British Association Medal Fund	32	7	9			
Library Deposits	3	0	0			
Subscriptions paid in advance .	10	0	0			
				£ 43	9	2
Library Binding and Equipment—						
Balance at 31st May, 1938 ...	35	1				
Add—Interest on Library Endowment Fund ...						
	21					
Less– Expenditure during ye	10					
					0	11
Revenue and Expenditure Acco						
Balanc at 31st May, 1938 ...	223					
Add– Excess of Expenditure over Revenue for the year ended 31st May, 1939						
					3	5
				1,378	3	6
Endowment Fund				3,085	4	5
Library Endowment Fund				2,164	1	6
South Africa Medal Fund				1,617	6	3
British Association Medal Fund				482	7	9
					3	5

				£	s.	d.
ash—						
On Hand	£3	3				
At Bank ...	68	3				
At Post Office Savings Bank, with interest accrued	)15	6				
At St. Andrew's Building Society, with interest accrued	83	4	1			
				£ 70	6	9
Sundry Debtors—						
For Advertisements in JOURNAL	47	5	0			
Trustees — Endowment Fund— Balance of Interest not paid over						
Trustees — South Africa Medal Fund for 1938 award and for expenses *re* 1938 and 1939 awards						
				29	2	11
Payments in Advance .				12	0	0
Furniture	68					
Less— epreciation . ..	8					
				60	0	0
edals on Hand				5	13	10
				1,378	3	6
Trustees' ndowment Fund— As per eparate account				3,085	4	5
Library dowment Fund— As per parate account ...				2,164	11	6
Trustees- outh Africa Meda Fund- As p separate account				1,617	6	3
Trustees- ritish Association Medal nd- As p separate account				482	7	9
				£8	3	5

We have examined the books and vouchers of the South African Association for the Advancement of Science for t y ded 31st May, 193 and certify that in our opinion the above Balance Sheet cor tly sets forth the position of the Ass ati the 31st May, 19 according to the best of our information and the explanation given to us and as shown by the books.

Johannesburg, 3rd July, 19

ALEX. AIKEN & CARTE An ors

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Dr. REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST MAY, 1939. **Cr.**

To Salaries			£180 0 0
,, Rent			63 0 0
,, JOURNAL Expenses		£1,042 5 8	
Less—			
Government Grant	£250 0 0		
Johannesburg Municipal Grant ...	100 0 0		
Sales, Reprints & Advertisements .	150 9 3		
		500 19 3	
			541 6 5
Printing and Stationery ...			25 19 11
Stamps and Telegrams ...			20 2 9
Insurance—Fidelity Bond and Workmen's Compensation ..			4 11 6
Expenses—			
Annual Meeting, 1938 (balance)		22	
Annual Meeting, 1939 (on account) ...			
			22 10 1
Sundry General Expe ses ...			42 0 9
Grants to Local Cent unde Rule 35—			
Witwatersrand		25 0 0	
Cape Province		8 18 0	
Natal ...		8 16 0	
Orange Free State		2 7 0	
			45 1 0
Depreciation on Office Furni			8 17 6
			£!

By Annual Subscriptions	£559 16 0	
,, Arrear Subscriptions	115 1 0	
,, Associates' Fees	30 0 0	
,, Students' Fees	6 5 0	
		£711 2 0
,, Interest—		
On Endowment Fund ...	127 14 1	
On St. Andrew's Building Society Account	2 4 11	
On Post Office Savings Bank Account	13 15 11	
		143 14 11
		854 16 11
,, Balance, being Excess of Expenditure over Revenue for year ended 31st May, 1939		98 13 0

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

ENDOWMENT FUND.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1939.

Dr.	£ s. d.	Cr.	£ s. d.
To Interest, as per contra, transferred to General Fund	£127 14 1	By Interest received during the year	£127 14 1
,, Balance transferred to Accumulated Funds	15 1 0	,, Life Membership Subscriptions	15 0 0
		,, Sale of Publications—British Association Account	0 1 0
	£142 13 1		£142 15 1

BALANCE SHEET AT 31st MAY, 1939.

Liabilities.			Assets.		
Amount due to General Fund ...		£10 15 2	Investments in hands of Trustees—		
Accumulated Funds—			Capetown Municipality 3¾% Stock	£1,150 0 0	
Balance at 31st May, 1938 ...	£3,070 3 5		Capetown Municipality 4% Stock	300 0 0	
Add—Amount transferred from Revenue and Expenditure Account	15 1 0		Capetown Municipality 5% Stock	240 0 0	
		3,085 4 5	Capetown Municipality 5% Stock	800 0 0	
			Port Elizabeth Municipality 3½% Stock	100 0 0	
			Cape of Good Hope Savings Bank	505 19 7	
		£3 5 19 7			£3,095 19 7

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

LIBRARY ENDOWMENT FUND.

Dr. REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST MAY, 1939. Cr.

To Balance transferred to Library Binding and Equipment Account	£75 16 4	By Interest received during the year	£75 16 4
	£75 16 4		£75 16 4

BALANCE SHEET AT 31ST MAY, 1939.

Liabilities.		Assets.	
Accumulated Funds—		Investments—	
Balance at 31st May, 1938	£2,164 11 6	£2,000 City of Johannesburg 3½% Local Registered Stock—at cost	£1,970 0 0
		Cash at St. Andrew's Building Society—Savings Bank Account	194 11 6
	£2,164 11 6		£2,164 11 6

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

SOUTH AFRICA MEDAL FUND.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1939.

Dr.	£ s. d.	Cr.	£ s. d.
To Expenses in connection with 1939 Award ...	£7 11 5	By Interest received during the year	£64 6 5
,, Amount of Award, 1939	56 15 0		
	£64 6 5		£64 6 5

BALANCE SHEET AT 31st MAY, 1939.

Liabilities.	£ s. d.	Assets.	£ s. d.
Amount Due to General Fund *re* 1938 Award .	£63 1 4	Investments in hands of Trustees—	
Sundry Creditors—		Fixed Deposit, South African Permanent Mutual Building and Investment Society .	£1,547 15 11
1939 Award and Expenses	64 6 5	Post Office Savings Bank	197 8 1
Accumulated Funds—			
Balance at 31st May, 1938	1,617 16 3		
	£1,745 4 0		£1,745 4 0

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE BRITISH ASSOCIATION MEDAL FUND.

Dr. REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1939. **Cr.**

To Award	£20 0 0	By Interest received during the year	£16 17 6
		., Balance carried to Accumulated Funds ...	3 2 6
	£20 0 0		£20 0 0

BALANCE SHEET AT 31st MAY, 1939.

Liabilities.			Assets.	
Accumulated Funds—			Investments in hands of Trustees—	
Balance at 31st May, 1938 ...	£486 0 3		£450 Union of South Africa 3¾ per cent. Local Registered Stock 1948/58	£450 0 0
Less—Excess of Expenditure over Revenue for year to 31st May, 1939	3 2 6		Amount due from General Fund	32 17 9
		£482 17 9		
		£482 17 9		£482 17 9

REPORT OF THE HONORARY LIBRARIAN FOR THE YEAR ENDED 31st MAY, 1939.

The Association's Library is housed in the Library of the University of the Witwatersrand, Johannesburg.

Hours of Opening.

Weekdays. Term: 8.30 a.m. to 7 p.m.
Vacation: 9 a.m. to 5 p.m.

Saturdays. Term: 8.30 a.m. to 12.30 p.m.
Vacation: 9 a.m. to 12.30 p.m.

Exchange of Publications.—Since the last report the following names have been added to the exchange mailing list:—

American Leather Chemists' Association.

Musée du Congo Belge, Tervueren, Belgium.

Société Mathematique, Amsterdam.

Donations.—Gifts other than exchange material have been received from the following:—

British Museum (Natural History).—*Marshall, J. F.: British Mosquitoes. Ticehurst, C. B.: Genus phylloscopus. John Murray Expedition: Reports, Vol. 5, No. 7. Economic Series: Nos. 3, 7a, 12. Summary Guide. Instructions for Collectors: Nos. 2, 13.*

Canada: National Museum.—*Canadian Arctic Expedition, 1913-18. Reports.*

Dr. E. Jokl.—*Some Modern Problems of Aviation Medicine.*

Dr. T. Kluge.—*Die Zahlbegriffe der Australier, Papua und Bantuneger.*

Linnean Society of London.—*Gage, A. T.: History of the Linnean Society of London.*

Onderstepoort: Veterinary Research Laboratory.—*Onderstepoort Library Index.*

Rhodesia, Southern: Parliament.—*Parliamentary Papers, 1938.*

South African Sugar Association.—*South African Sugar Year Book, 1935-37. South African Sugar Association: Proceedings, 1928-1934. Report of the Delegates to the 4th Annual Congress of the International Society of Sugar Cane Technologists.*

Dr. B. Smit.—*The Cyanide Fumigation of Citrus Trees.*

Miss H. M. White.—*South African Journal of Science: Vols. 1-34, 1903-37.*

Binding.—227 volumes have been bound during the year.

Stock.—The Library now contains about 3,000 volumes. Periodicals currently received number 275.

Accessions to Serial Publications, 1938-39.

For a *Catalogue of serial publications in the Library* and *Supplement*, see this Journal, Vol. xxx, pp. xxv-xxix and Vol. xxxiv, pp. xxxiv-xxxvii.

A.W.A. Technical Review. [3, 1938; 4, 1939+.

American Leather Chemists' Association. Journal.34, 1939+.

Association Canadienne, française pour l'advancement des sciences. Annales. 1, 1935+.

Canada. Dept. of Transport. Annual Report. 1937/38+.

Chicago Naturalist. 1, 1938+.

Cuerpo de ingenieros de minas del Peru. Boletin. Nos. 110-112, 1934-35; 118, 1937+.

Gesellschaft naturforschender Freunde zu Berlin. Sitzungsberichte. 1936+.

La Plata. Universidad nacional. Publicaciones. No. 94, 1932+.

Leyden. Rijksuniversiteit. Sterrewacht. Annalen. [15, 1930-34; 17, 1937+.

Lund. Universitet. Acta universitatis Lundensis. 31, 1935+.

Manchoukou. Institute of scientific research. Report. 1, 1937+.

Mexico. Museo nacional de arqueologia, historia y etnologia. Annales. 1-2, 1934. Boletin. 1, 1934.

Review of Physical Chemistry of Japan. 11, 1937+.

Royal Astronomical Society of London. Occasional notes. 1, 1938+.

Salisbury. Queen Victoria Memorial Library. Occasional paper. 1, 1938+.

Transvaal Museum. Report. 1935+.

Warsaw. Panstwowe muzeum zoologiczne. Acta ornithologica. 1, 1933+. Annales musei zoologici polonici. 1, 1922+. w. 12. Fragmenta faunistica. 1, 1930+. Sprawozdanie. 1929.

Washington. University. Publications in anthropology. 5. 1932+. Publications in biology. 1, 1932+ [1. Publications in geology. 1, 1916; 3, 1931+.

Abbreviations and symbols used:—

+ indicates that the set is complete from the last volume or number given.

[indicates that the volumes following are incomplete.

w. indicates that the volumes following are wanting.

P. FREER,
Honorary Librarian.

University of the Witwatersrand,
Johannesburg.
1st February, 1940.

OBITUARY.

Professor JOHN WILLIAM BEWS, M.A., D.Sc. (Edin.), 1884-1938.

John William Bews was born in Scapa, Orkney. He early showed exceptional ability, and in the course of his school and university career was the recipient of many prizes, bursaries and scholarships, with which he was able, from the age of fourteen, to pay for his own education.

After graduating from the University of Edinburgh he was appointed lecturer in Economic Botany at Manchester in 1907. In 1908 he returned to Edinburgh as Assistant Professor of Botany and Lecturer in Plant Physiology. In 1910, at the early age of twenty-five, he was appointed Professor of Botany in the Natal University College, Pietermaritzburg.

Bews immediately threw himself wholeheartedly into a study of the ecology of the Natal and South African vegetation, on which he published a steady stream of papers and books from 1912 until 1929. His most important botanical books were: "Grasses and Grasslands of South Africa" (1918), "Plant Forms" (1925), "Ecological Evolution of Angiosperms" (1927), and "The World's Grasses" (1929). In addition to his own research he built up a strong department of Botany at the Natal University College, and was a most inspiring teacher. Former students of his hold university and research appointments in various parts of the British Empire.

Bews occupied a prominent position on the administrative side of scientific and educational affairs in this country. He was several times Chairman of Senate of the University of South Africa, member of the University Council, of the Joint Matriculation Board, and of the Research Grant Board. He was for many years a member of Council of this Association, and served the Association in several capacities. He presided at the Grahamstown meeting in 1931, and was awarded the South Africa Medal and Grant in 1932.

In 1931 Bews was appointed first principal of the Natal University College. After this appointment his time was so occupied with the difficulties of administration in a rapidly growing institution that he was forced to relinquish his active botanical research. As relaxation from administrative worries he turned to general scientific philosophy, and to studies in human ecology. On this subject he published "Human Ecology" in 1935 and "Life as a Whole" in 1937.

The nature of Bews' scientific and educational interests made it necessary for him to visit frequently various centres in this country. His unaffected, friendly, manner and wide knowledge, gained him many contacts with his fellow-men, so that he became one of the best known of South African scientists.

The chief characteristics of his work were ready appreciation of the exact implication and significance of facts, the ability to stand back and see the picture as a whole, and the speed of his generalisations. The big view was perfectly natural to Bews and suffused his whole attitude to life. It was these characteristics which gave him that great wealth of knowledge, put him in the top flight of scientific ability, and made him an able administrator and a wise and sympathetic councillor.

Early in his student days Bews suffered a serious illness of pleurisy with effusion. It was the extension of complications arising from this illness aggravated by overwork, which led to his death last year at the age of fifty-three. His loss has been deeply felt by his friends and in scientific and educational circles in this country and overseas. To the Natal University College and to Mrs. Bews the Association extends its sincerest sympathy in their great loss.

A. W. B.

The price of this Journal to the general public is as marked on the front page. Every member of the Association is supplied with one copy free, and may obtain extra copies at half-price. Applications for copies should be addressed to the Assistant General Secretaries, P.O. Box 6894, Johannesburg.

CORRESPONDENCE.—All communications other than those relating to the Journal **should be addressed to the Assistant General Secretaries, P.O. Box 6894, Johannesburg.** (Telegraphic address: "Science, Johannesburg.")

Communications for the Editor should be addressed to the Botanical Department, The University, Milner Park, Johannesburg.

PAPERS for publication should be condensed and limited as far as possible to the description or discussion of new facts, new observations, or new ideas. They should be typewritten and carefully corrected.

ILLUSTRATIONS (other than photographs and half-tones) accompanying papers intended for publication in the Journal must be supplied by the authors, carefully drawn about **twice the size** of the finished block, on smooth white Bristol board, in **India ink,** so as to admit of the blocks being prepared directly from the drawings. Any lettering on these drawings should be of such a size that it will be clearly legible when reduced. For graphs, squared paper ruled in pale blue **only** should be used, otherwise the ruled squares appear black in the photographic reproduction. The size of the printing area of a page of the Association's Journal, including space for legends, is 7in. × 4in.

The attention of authors is also directed to the first paragraph of By-law 6, requiring them to submit abstracts of their papers, together with the original papers, to the Recorder of their Section **at least a fortnight** before the beginning of the Annual Session.

REPRINTS.—Authors desiring to have reprints of their papers, read at the Annual Meeting of the Association, are requested to notify the Editor as soon as possible as to the number required, or, at latest, when returning their proofs.

LOOSE COVER CASES.—Cases uniform with the covers of previous volumes may be obtained for binding on application to the Assistant General Secretary, at a cost of 5s. per case post free.

SUBSCRIPTIONS.—Subscriptions of £1 10s. for the year ending 30th June, 1940, are now due. Members are requested to remit this amount as soon as possible to the Assistant General Secretaries, P.O. Box 6894, Johannesburg. Unless members pay the amount due at an early date, great inconvenience and unnecessary expense is caused, as it is very difficult to determine what number of copies of the Journal will be required. The Council therefore appeals to every member for support and co-operation, and asks that outstanding subscriptions be paid without delay. **The Journal will be sent only to those whose arrear subscriptions are paid.**

Cheques, etc., should be crossed and made payable to the **Association, not to the Secretaries or Treasurer individually**. Sixpence should be added to country cheques for exchange.

HEADQUARTERS.—The offices of the Association are located in the building of the Associated Scientific and Technical Societies of South Africa, Kelvin House, corner of Hollard and Marshall Streets, Johannesburg. The postal address of the Association is "P.O. Box 6894, Johannesburg," telegraphic address, "Science, Johannesburg," and telephone number 33-5710.

Johannesburg, December, 1939.

South African Journal of Science, *Vol. XXXVI, pp. 1-18, December, 1939.*

SCIENCE AND THE METALLURGIC ART

BY

G. H. Stanley,

Professor of Metallurgy, University of the Witwatersrand, Johannesburg.

PRESIDENT.

Presidential Address delivered 3 July, 1939.

Mr. Chairman, and ladies and gentlemen, who, whether members of our Association or not, have demonstrated your interest in the progress of science by your presence here to-night, I would in the first place express to you my deep appreciation of the privilege of addressing you, and to the members for the great honour conferred upon me in electing me to the Presidential chair, and thus laying upon me the duty of giving this address.

It is, of course, traditional that I should deal with a subject about which I am supposed, at least, to have some special knowledge, and it occurred to me that it might be of interest to endeavour to show how extremely important the metals, with which it is my avocation to deal daily, are to our modern civilisation.

But a very brief consideration convinced me that I could say nothing of which you were not already well aware. For all our modern requirements, for food, housing, clothing, for transport, for all the amenities which to-day, as we think, make life worth living, we have obviously to depend in various ways and in varying measure on the use of metals. Our civilisation indeed would be of a very different character if no metals were available.

What is by no means so obvious, however, is the fact that in bringing the use of metals to its present state of development, the inherent useful properties of metals, as compared with those of alternative materials, flint, wood, horn, etc., have been modified in many ways in order to better adapt them to the purpose in view.

Primitive man, for example, was quick to appreciate the advantage of a piece of native copper compared with flint for the manufacture of an arrow head. He could beat it to shape, and if it became deformed in use it was not irretrievably ruined, but could be straightened. True, it was not so sharp, but the balance of advantages against disadvantages was in favour of the former, and when later he found it possible to melt it and thereafter cast it into a mould for an axe or spear head, the art of metallurgy may be considered to have originated. Just

how, or when, it was discovered that this desirable material could also be obtained by heating certain stones, or, as we say now "ores," in the fire will probably never be known, but someone observed the fact and "smelting" began. After that, it was but a step to find that different stones yielded different metals, e.g., tin and iron, with different properties. The one white, soft, easily melted—the other grey, hard, impossible to melt: the white tin when melted with copper, making a yellow alloy—bronze—in many ways an improvement over copper, harder, easier to melt, and easier to cast; while the grey iron, although infusible, could be forged to shape and was stronger and kept a keener cutting edge than bronze.

These simple examples will serve to illustrate what is meant by the term metallurgy, of which the definition given by the eminent metallurgist, Dr. Percy, about the middle of last century, can hardly be improved upon—i.e., the extraction of metals from their ores and adapting them for use.

Even in his day, however, metallurgy was still regarded rather as a practical art than as a science, and I think that if I now attempt to give some account of the results of scientific research and methods of investigation and control applied to this old practical art, it will at least not be devoid of interest.

Broadly speaking I regard "science" as giving the "reasons why" and the "art" as the "means how" involved in a series of operations.

Let us consider first iron, that metal upon which, more than any other, our present mode of life is based. Although possibly the first to have been intentionally smelted by the crude and simple method of heating iron ore and charcoal together (a method still used on this continent) progress in the art was extremely slow. Although the production of cast-iron was known in China in 200 and perhaps 400 B.C., and the Romans knew that by heating soft iron with certain other materials it could be made harder, and still harder by heating it and quenching in some liquid, there was no knowledge of the underlying reasons till the Swedish chemist, Bergman, in 1781, demonstrated that it was in effect the presence of carbon in iron which converted it to steel.

Hitherto, magic virtues had been attributed to the material used and certain propitious circumstances were considered essential to the proper conduct of the smelting operation.

Following Bergman, scientists showed that the properties resulting depended primarily on the amount of carbon absorbed by the metal, and that this was affected by the circumstances of treatment. As usual, there was some controversy till in 1815 Pepys caused an electrically heated iron wire to melt by bringing it into contact with pure carbon in the form of diamond dust.

Before this discovery there had naturally been some progress in the direction of enlarging the smelting furnaces employed and increasing the output. In the course of this development higher

furnace temperatures were attained and the metal sometimes melted—forming " cast iron." No doubt this was a considerable nuisance in the beginning, as the metal was not amenable to the methods of shaping by forging employed for the wrought iron. However, its utility for the manufacture of required shapes by casting was at length realised and gradually cast iron in various forms came more and more into use, though in Europe, not till about 1350. This early cast iron was the so-called " white " iron: very hard and very brittle, and its suitability for certain purposes was consequently limited. With the gradual growth of furnaces and the employment of stronger blast and higher temperatures a different kind of iron—grey cast iron—began to be produced and much later on chemical science showed that this was to be attributed to the presence of yet another element, silicon, in the iron, the effect of which was to cause most of the carbon, hitherto chemically combined in the iron as hard carbide, to be thrown out of solution as soft graphite, interspersed through the mass of soft iron.

With these facts in mind, it became possible to determine the factors in furnace operation upon which the amounts of carbon and silicon present depended and to produce to order white, grey and various intermediate forms of cast iron adapted to the many requirements of industry.

At this stage then the materials available were wrought iron, a soft, tough metal, weldable, readily forgeable by the smith, but too soft to keep a good cutting edge if formed into tools; steel of different hardness and strength according to its carbon content, capable of being forged into tools and being still further hardened by " quenching " and " tempering;" and lastly, various grades of cast iron, which, being brittle, could only be obtained in the required shapes by running while molten into suitable moulds, but relatively widely used because if its cheapness.

When the underlying chemical differences were beginning to be realised, a great step forward was made by Cort, who, in 1784, devised a method of removing carbon from cast iron, and so making wrought iron, which the relatively large furnaces producing cast iron could not make directly.

His process, as modified by Rogers in 1818, and still in use to a small extent, consisted in melting the cast iron with iron oxide in a small " puddling " furnace, the result being that the carbon (and silicon) was oxidised, and the soft pure iron, which incidentally is less fusible than the impure cast iron, was removed from the furnace and hammered into bars just like that from direct reduction.

Steel, however, was still made by adding the required amount of carbon to these bars by heating them while embedded in charcoal, the operation taking a week or more, and then subsequently forging into the tools required, or alternatively, in a later development, melting in crucibles, casting into ingots, and forging down.

That brings us to about 1850, and as compared with the present position, all the metals except cast iron were relatively costly and production was small, the annual output of pig iron in England, the largest producer, being 2¼ million tons. In 1855, the production of steel in England was only about 50,000 tons, and the price up to £75 per ton.

About that time the chemist Bessemer, in London, conceived the idea of effecting the removal of carbon from cast iron, and so converting it to steel, not by melting it with an oxidiser, but by burning out the carbon by blowing air through the molten iron and with that the modern steel age may be said to have commenced.

When this process got fairly under way, the price of steel was lowered to a figure permitting of its use for large engineering projects such as railroads (1862) and bridges and ship building (1863) on a scale hitherto impossible. There were, however, initial difficulties to be overcome, for which chemical science again found the remedies. In short, if the blowing was inadvertently too prolonged, the steel produced was brittle, and failed in service, giving rise, very naturally, to a lack of confidence in the new material. The remedy was found in the addition of one of the newer metals, manganese (discovered less than a century previously by Gahn), which takes from the steel the excess oyxgen which caused the brittleness and also to a very large extent obviates the bad effect of the presence of a little sulphur. So essential in fact is manganese that all modern steel contains it in small proportions, something like one-half of one per cent.

However, it soon became apparent that this process had its limitations; there were certain ores from which excellent pig iron could be produced, and which, by the older puddling process, could be made to yield wrought iron and thence steel by cementation, and yet by this newer process would not produce good steel.

Chemistry gave the answer to the question "why?" It was due to the presence of the element phosphorus, the effect of which is so injurious that no more than 0·06 per cent. is allowed to be present to-day in even the lower or inferior grades of steel. The cure, however, was not so easy to find, and this was a serious matter, for the non-phosphoric "Bessemer" ores are available in very much less quantity than others. Nevertheless, the cure was found, and once again it was a chemical one.

The early converters were lined with a highly silicious material, metallurgically speaking an "acid" material. The iron also contained silicon which was oxidised during the blow, so that the slag formed was acid, and under these conditions the phosphorus remained in the steel. Snelus, Thomas and Gilchrist discovered in 1872 that if the steel was melted with a basic or limey slag instead, the phosphorus left it and passed into the

slag. This discovery resulted in the employment of a "basic" lining for the converter coupled with the addition of lime, and thereafter the more phosphorus present the better, for the chemist soon discovered that the highly phosphoric "basic" slag, after fine grinding, constituted a very valuable fertiliser.

So far I have dealt mainly with the influence of chemistry on the development of steel manufacture, but the assistance of the allied science of physics has been of no less importance.

About the time that Bessemer was approaching success with his experiments, the Siemens brothers were interesting themselves in the production of higher industrial temperatures by means of preheating the air and gas used in developing heat in furnaces. They devised a furnace for glass melting, in which an interchange of heat, which otherwise would have been lost up the chimney stack, was brought about between the waste gases, and the incoming gas and air, by passing them in alternate directions through chambers containing refractory brickwork, the direction being controlled by suitable valves. This enabled much higher temperatures to be attained much more economically with respect to fuel consumption than had previously been possible, and it was not long before the new furnace was adapted to steel manufacture, i.e., about 1860.

Long before this, Huntsman, in Sheffield had initiated —about 1770—the "crucible" process of steel making by melting cemented steel in crucibles, and so producing the "crucible cast steel" on which the fame of Sheffield was largely founded. It was also possible to make steel, though less reliably, by similarly melting wrought iron with charcoal or better still, with "white" cast iron, in proportions requisite to produce steel of the required carbon content. It was necessarily a costly process, up to three times as much coke being required for firing as there was steel produced, quite apart from the cost of the crucibles and labour.

The Siemens' furnace was able to melt such materials cheaply, the operations were well under control, the phosphorus difficulty could be dealt with by providing a basic lining as in the Bessemer, and although a "heat" takes longer, several hours as against a fraction of an hour in the Bessemer, the furnaces can be made much larger, even of 300 to 400 tons or more capacity, so that, although at first the process lagged behind the Bessemer in its development, in course of time it far outstripped it, and to-day it is responsible for the major part of the world's steel output, now bordering on 100 million tons annually.

In its operation, both chemistry and physics are constantly in evidence, the chemical analyses of all the raw materials, now scrap steel, pig iron and iron ore for oxidation, in various proportions, must be known. The principles of action of the slag, which has to remove the impurities chemically, are understood, and depend very considerably on the furnace temperature, which, as well as that of the steel, finally is ascertained by pyrometers

devised by the physicist. Before being cast, the composition is determined by the chemist, and even the chemical composition of the fire-brick and other materials used in the construction of the furnace has to be specified, and its behaviour in resisting heat determined by physical methods, which are also employed in testing the quality of the final metal. The customer is not content to be told he is getting good steel, he has to be told precisely how many tons per square inch it will resist, and so on.

These developments in steel making obviously called for rapidly increasing production of cast iron. Before Bessemer's invention, blast furnaces had been developed to produce about 50 tons per day, and had a height of about 25 to 30 feet, occasionally up to 50 feet. Coke, of course, had largely displaced the charcoal originally employed as fuel, but they were still "blown" with cold air and used about 2 or 3 tons of coke per ton of iron produced.

It occurred to Neilson of Glasgow, that if he heated the air before blowing it into the furnace, and so supplied additional heat, an improvement of performance would result. This was found to be the case to an altogether unexpected degree, and the employment of this "hot blast" so reduced the amount of coke required, that the practice extended rapidly, and instead of allowing the waste gas to burn at the furnace top, it was utilised in suitable "stoves" to pre-heat the blast air, thus effecting a double fuel economy. So far, however, the chemistry of the process was rather obscure, but in 1872, a chemical investigation into the working of blast furnaces by Sir Lowthian Bell, led to a much better understanding of the main principles of their operation and progress became still more rapid, until of recent years, many furnaces 100 feet high produce 1,000 tons per day. As with steel, all the raw materials, iron ores, fluxes, and fuel must be accurately analysed, so that they may be charged into the furnace in the correct proportions to produce iron of the required grade or analysis for the purpose in view. Sulphur must be kept out, silicon perhaps brought in, as required, and, of course, chemical analysis is made to ensure that these, and other elements, are present to the desired amount. Temperatures also have to be carefully ascertained, blast pressures and volumes measured, again making use of the physicist.

So far, I have mentioned only ordinary iron and steel, materials which owe their different properties mainly to the different amounts of carbon contained, and hence commonly known as carbon steel.

Comparatively recently, another class of steel, owing extraordinary properties to the addition of other elements than carbon has assumed great importance, but time does not allow giving them much more than mention to-night, and I will draw your attention now to the manner in which our knowledge of the causes of the different behaviour and properties of the various kinds of steel has been elucidated by pure scientific research.

Dr. Sorby, in Sheffield, about 1864 began that study of the internal structure of metals under the microscope, which has since grown into the science of metallography.

His method, briefly, consisted in preparing a perfectly flat highly polished section, lightly attacking or "etching" it with a suitable medium, e.g., dilute nitric acid, and then examining it microscopically by reflected light. At once it became evident that he was dealing with heterogeneous substances, wrought iron consisted of grains of pure iron with more or less entangled slag; in grey cast iron, this pure iron was mixed with graphite and another grey constituent; white iron was composed of two constituents, the one grey and soft, the other white, but very hard; steel of medium hardness contained the soft white constituent of wrought iron, and the same grey one found in grey cast iron, but in hard steel the structure was mainly composed of this grey constituent, with possibly some of the hard white constituent of white cast iron. These constituents received the names of ferrite, pearlite and cementite; the first pure iron, the last iron carbide (Fe_3C) and the other an intimate intergrowth of these two in the form of an aggregate of thin plates. The relative amounts in which these constituents are present chiefly determine the properties of the material, and these depend in turn on the chemical composition, mainly, as previously stated, on the percentage of carbon. Not, however, entirely on the amount of that element, but on the way in which it occurs. While iron and grey iron may have just the same amount of carbon. Why then the difference? The answer lies in the amount of silicon present. Silicon tends to render carbon insoluble in iron, and consequently when silicon is present, the carbon is thrown out of solution and appears as graphite.

This, however, does not afford an explanation of the different degree of hardness which is conferred upon steel by heating and quenching it—there has been no change in chemical composition in that case. What now is the reason? The answer is as before, it is due to the way in which the carbon exists.

I have stated just now that under the microscope a piece of medium hard steel is seen to consist ordinarily of ferrite and pearlite, after heating and quenching the microscopic structure is entirely different, it consists of a new hard substance termed "martensite" in honour of a noted German metallographer, and this is a "solid solution" of carbide in iron. Very hard indeed, but too brittle for general use, and so tempering follows and restores a certain measure of toughness while leaving the metal still hard enough for use as a tool.

What happens is that when the metal is heated to bright redness, the carbon (or carbide) dissolves in the iron, if it cools slowly, it comes out of solution again, and appears as pearlite under the microscope. If it is, instead, quenched, there is not sufficient time for this to happen, and so it is retained in solution; but when, in tempering, it is again carefully heated to a lower

temperature, this coming out of solution begins to take place and the metal begins to soften, and is stopped again by re-quenching when the desired effect is obtained.

By physical experiments, the exact temperature at which the carbon begins to dissolve, and at which the dissolution is complete have been determined, and are known as the " transformation points " and the degree of tempering is, of course, controlled also by pyrometric measurement of temperature. Naturally enough, operations of this nature are referred to as " heat treatment."

Now, perhaps, we may return for a moment to the " alloy steels " which owe their special properties to other elements than carbon, though carbon is generally also present.

Manganese, present normally in small amounts in steel for reasons already mentioned, when alloyed in considerably larger proportion, 14 per cent. or thereabout, produces a material with quite extraordinary properties. Scientific investigation shows that the effect of the manganese is to lower the transformation point to below ordinary room temperature instead of red heat, and consequently at ordinary temperatures the steel is in the state in which carbon steel is at high temperature. It is, in fact, non-magnetic, and particularly distinguished by the possession in extraordinary degree of the property of " work hardening," which renders it extremely resistant to wear when used for such purposes as railway points and crossings, and faces of rock crushing and grinding machinery, for which it is consequently widely used.

Nickel increases in marked degree, the property of toughness as indicated by increase of tensile strength without loss of ductility, and considerably increases also the resistance to rusting or corrosion. Hence nickel steel with about 3½ per cent. nickel, is used for boiler plate, axles, etc.

The thermal expansion is also profoundly affected, and with about 36 per cent. of nickel, a substantially invariable alloy known as " Invar " is obtained, particularly useful for timepiece pendulums, measures of length, and so on.

Chromium very greatly increases the power of steel to harden on quenching, so that this variety also is in use for rock crushing machinery and special tools. In addition, resistance to corrosion is so marked that by suitably proportioning the chromium, a non-rusting alloy is obtained, the original and now familiar " stainless steel."

Tungsten so markedly raises the transformation point, while conferring hardness, that these steels are not softened and remain tool hard when heated as in tempering other steels. They are termed, therefore, " self-hardening " steels.

Remarkable as are the results obtained by adding manganese, nickel or chromium to the steel, still more striking effects result from the combination of two or more elements present together.

Tungsten and chromium give us "high speed" steel, of which tools are made capable of working even when the speed of cut causes them to heat to redness. Nickel and chromium give the combination of strength and hardness so desirable in motor car gear wheels, while conferring such rust and oxidation resistance that the modern "stainless steel" and heating elements for our domestic electric stoves and irons as well as metallurgical furnaces are fabricated therefrom. Other elements, e.g., vanadium and molybdenum are also frequent additions to these special steels for special purposes, and some of the resulting effects on properties are mentioned and compared with those of other materials in the following table:—

TABLE I.

	Tensile strength, tons per sq. inch	Yield point, tons per sq. inch	Elongation per cent.	Izod impact value
Pure Iron (Ingot Iron) ...	20	11·5	43	—
Wrought Iron	23	14	30	—
Pig Iron	8	—	nil	—
Steel (0·3% Carbon) annealed	31	16	24	24
Steel (0·65% Carbon) as rolled	50	—	22	—
Steel (1·15% Carbon) as rolled	56	38	7	--
Steel (3% Nickel, OQ & T.)	52	43	26	78
Steel (3½% Nickel, 0·7% Cr)	60	55	22	68
Steel (1½% Nickel, 1¼% Cr, 3% Mo) tempered 200° ...	122	102	13	16
Steel (1½% Nickel, 1¼% Cr, 3% Mo) tempered 600° ...	63	58	21	59

As may be expected, the precise effects are dependent on the percentage present, and have been ascertained only by most exact chemical and physical experimentation, and it follows also that in their manufacture, very close chemical and physical control is essential.

Now while the various properties are largely correlated to the microstructure, and that in turn is affected by heat treatment, the question still remained, why does the composition and heat treatment affect the structure?

The answers are to be found in considerations of much more fundamental character connected with the molecular structure

of the crystals of which all metals are composed, and which even now is still in process of elucidation. Such great progress, however, has been made that it is at length possible even to advance some explanation of why certain elements exhibit metallic properties, and others non-metallic, and without attempting to be very abstruse, some indication of the nature of the evidence will, I think, be of interest.

It is to X-rays, to which so much of our knowledge of the atom is to be attributed, that we are indebted for the great progress made during the last few years.

Discovered by Rontgen, while I was in my student days at the Royal School of Mines, it was later on demonstrated that X-rays were similar in nature to light, and also to Hertzian or "wireless" waves, which had been discovered a few years earlier. The essential difference was in the "wave-length" of these manifestations, which later were found to be of the order 10^{-8}, 10^{-5}, and 10^{5} cms. respectively. That is, the wave length of X-rays is only 1/1000 that of light, and whereas the latter is stopped or reflected by most substances (except the few transparent ones) the former are able to penetrate most substances because they are able to slip through—so to speak—between the atoms or molecules of which material substances are composed.

Now it is common knowledge that "white light" is a mixture of light of various colours evidenced by its separation into these colours by use of a prism, and the same effect can be brought about by using a "diffraction grating" consisting of a number of closely ruled parallel lines on glass. However, it was quite impossible to rule lines sufficiently closely together to affect X-rays in this way, because of their extremely small wave length, and it was only in 1911 that Laue suggested that the atoms in a crystal, which from other considerations were assumed to be arranged in definite patterns of lines and planes, might be used as diffraction gratings, and this was soon proved experimentally.

We now know that if any element is bombarded by electrons, i.e., when it forms the target of an X-ray tube, X-rays are emitted of wave length dependent on the "atomic weight" of the element as well as on the energy of the electrons (depending on the voltage employed). We can also "filter" off certain of these wave lengths and transmit others by using thin sheets of certain metals, just as coloured filters are used in the case of light, and so can obtain beams of "monochromatic" X-rays of definite wave lengths. These can then be used in the examination of crystal structures, and using the Bragg law—$n\lambda = 2d \sin \theta$, when n is any whole number, λ the wave length, d the interplanar distance and θ the grazing angle, the actual distances involved in the crystal structure can be determined.

As a result of this work, the actual arrangement of the atoms (or ions) in crystals has been arrived at, and their distance

apart measured, and just as on a piece of ordinary trellis or "lattice work" the intersections make a regular 2 dimensioned pattern in a plane; a lattice work in 3 dimensions, with the atoms placed at the intersections, gives a graphic representation of what is termed the "space lattice" of the crystal.

The atom according to the modern view is electrically neutral and consists of a positive nucleus surrounded by electrons at various distances, some of which, those in the outer "shell," determine its "valency" and in the case of metals are responsible for its metallic properties. When atoms combine to form a compound or build up a crystal, they may do so by electron transfer, e.g. when Na (sodium) with one valency electron outside a stable shell of 8 gives it up to Cl (chlorine) which has seven, and so forms a stable 8, resulting in a combination of 2 ions held together by electrostatic attraction, an example of ionic linkage; or by electron sharing e.g., when 2Cl, each with 7 valency electrons, shares one of these with the other, again making stable shells of 8, 6 unshared and 2 shared, and giving an example of covalent linkage as in the diamond. But with metals it is difficult or impossible to conceive of groups of 8 stable electrons in this simple way and to quote Hume-Rothery, "when there are not sufficient valency electrons per atom to build up stable groups of ionic or covalent bonds, the need arises for a new kind of linkage in which the electron serves for more than 2 atoms, and in this way the metallic linkage comes into being, and since the electron is no longer confined to a particular atom or pair of atoms, we can understand why electrical conductivity is shown." "We accept it as a fact that a metallic crystal consists of a number of positively charged ions arranged in a regular pattern" and that electrons occupy points on the lattice between atoms; or we can assume the ionic type of structure, with the negative ions electrons instead of atoms.

Metals, then, being crystalline bodies, have characteristic space lattices, not constituted as in other crystals of an assembly of neutral atoms, "but rather as an assembly of positive ions held together by the attraction of intervening valency electrons," and it has been determined that these are altered by heat treatment and by the presence, as in alloys, of other metals.

X-rays therefore afford a means of investigating these changes in properties of metals brought about in various ways and constitute one of the most important and useful tools available to metallurgists, and I may perhaps indicate some of the directions in which a fuller understanding has resulted from their use.

It is almost common knowledge that a metal exhibiting large crystal faces on fracture tends to be relatively brittle and weak. The mode of formation and growth of crystals has been studied and elucidated and among other things, the formation of an intercrystalline cement demonstrated and explained, which

normally hinders further growth. If, however, this is perforated, as in hammering or rolling, the crystal is able to resume growth through it on further heating, e.g., in annealing, and very coarse crystallisation may result.

Further, imperfection rather than perfection has been shown to be the natural structure of a crystal owing to various factors involved in its growth, hence a sort of mosaic structure is present owing to the sections having not quite, although very nearly, the same direction or orientation, thus causing planes of weakness along which slip takes place on deformation as well as on planes within the crystal parallel to the space lattice.

This knowledge of the structure of crystals has afforded an explanation of the fatigue of metals. Many repetitions of stress, particularly alternating stress, and resulting strain quite insufficient to permanently deform—much less break—a metal part, such as motor axle shaft, cause minute cracks to appear on the slip planes which eventually develop into large cracks and fractures.

It has also enabled the elucidation of "age-hardening," a method developed within the last quarter century. A German chemist, Wilm, in 1911, noticed that an alloy of aluminium with a few per cent. copper and a little magnesium, after quenching from 500°C. had hardened after several days' rest, and that this occurred very quickly if it was heated to quite a low temperature, about 200°, with accompanying increase of strength. This material, now known as Duralumin, has several times the strength of aluminium, but the reason was at first obscure. A few years later, it was found that the solubility of copper in aluminium below 500° is very limited, and after quenching the copper slowly comes out of the solution forming a compound $CuAl_2$. The suggestion was made that this separates as small particles on the slip planes, where it functions as "pegs," preventing or retarding their slip, and X-ray examination as recently as 1926 apparently confirmed this view. There were certain anomalies, however, which were finally explained by Merica—an American scientist—in 1932—who suggested the formation of "knots" of disturbed and concentrated copper atoms undergoing transition on and from the aluminium lattice, or in course of formation of $CuAl_2$.

Similar phenomena, known now as "precipitation hardening" occur in other alloys such as aluminium-manganese, copper-beryllium, copper-nickel-silicon, copper-nickel-aluminium, lead-antimony, lead-calcium, iron-molybdenum, and even in low-carbon steel. The case of the copper-beryllium is particularly striking; copper is ordinarily much less strong than steel, but copper containing 2 per cent. beryllium, by a double cold working and heat treatment process has been given a strength and hardness more than thrice that of ordinary steel.

Recrystallisation and grain growth are also well understood as a result and while it must be admitted that many of these useful phenomena were known and utilised before the explanation was available, it is early yet to predict what the effect of this knowledge will ultimately be when taken advantage of, as in the case of earlier scientific discoveries, as a guide to further developments in the field of metallic alloy production and utilisation.

As an indication, we may glance briefly at some of the more recent developments.

Ferrous metals and alloys—special steels or alloy steels have already been mentioned. For the multifarious needs of industry an extraordinary variety of these is now available—varying from the practically pure " armco " ingot iron, soft, malleable, rust resisting, possibly the best material for our galvanised corrugated roofs, to, at the other extreme, special tool steels, hard enough to scratch glass. Some which can be rolled into thin sheet for the tin-plate of our canned foodstuffs and others so brittle that an abrasive powder can be made by crushing. Most of them so liable to rusting that they cannot be used for long without special protection. Others definitely non-rusting. Most of them liable to severe oxidation or scaling and rapid destruction when maintained at red heat for any length of time; some specially resistant and able to give long service under such conditions, and so on. It would take too long to enumerate the range of properties available as a result of the employment of scientific control of composition and method of manufacture.

Iron and steel amount by weight probably to 90 per cent. of the world production of metals, the other 10 per cent. being made up of about 30 other non-ferrous metals, among which, copper, lead and zinc account for 9 per cent. All these three have been obtained by time-honoured " fire " methods for centuries with but little " science " to guide the operation till comparatively recently.

Perhaps the most notable application of science to these older methods in their case was the application of electro-deposition.

We are all familiar with the process known as electro-plating, arising from the experiments of the great Faraday. It is now used for coating metals with other metals for appearance sake, corrosion resistance, etc. But it is also employed for purifying or electro-refining certain metals on the large scale, notably in the case of copper. Copper, of course, is the most widely used of metals for conduction of electricity, but its utility for this purpose is seriously affected by a number of common impurities. Consequently, as originated by Elkington in South Wales in 1865, the crude copper obtained by smelting ores is cast into the form of plates—" anodes "—which are placed in vats containing an electrolyte—acidified copper sulphate solution—and transferred to " cathodes " by electrolysis, leaving the impurities (including gold

and silver) either in the solution or insoluble as slime. The pure cathode copper is melted and cast, and probably 90 per cent. of all copper is now refined in this way.

The process is also applied to lead, for separating contained silver and gold; to nickel, so separating the platinum usually associated with it; and is also used as a means for separating gold and silver from one another and from platinum. It affords in addition a means for the treatment of copper ores, from which in certain cases the copper may be dissolved in sulphuric acid, and then electro-deposited.

Zinc, also, is now in some cases, extracted in the same way. The application of the method in the latter case, however, presented many difficulties and much real scientific research has been needed to overcome them and enable the process to be successfully operated, so that it is worthy of more than passing mention. It seemed simple enough, as in the case of suitable copper ore, to dissolve out the zinc from oxidised or roasted ore with sulphuric acid, and then recover the zinc by electrolysing the solution, but the zinc would come down in branching crystalline forms very awkward to deal with and melt, instead of in coherent sheets, or when partly deposited would start to redissolve and so nullify the operation.

Electro-chemists gradually traced the causes and provided remedies. Very careful attention is necessary to the purity and acid strength of the solution. Copper, nickel, cobalt, even the rare metal germanium are removed by appropriate chemical means of purification and the result is seen in the regular commercial production by this method of zinc of a very high degree of purity.

Now the zinc hitherto available, produced by the old distillation process, was of much inferior purity and for many purposes much less desirable than the pure electrolytic zinc.

Consequently, a means was sought to purify this other grade of zinc, and was found in America in the adaptation to this purpose of the method—fractional distillation—used in purifying more familiar chemicals—alcohol, etc.

Some idea of the attendant difficulties may be inferred from the difference of temperatures—the distillation of the metal being carried out at over 1000°C. and it is only possible by utilisation of a product of the sister science of electro-chemistry—carborundum—for construction of the necessary apparatus. Incidentally, cadmium, which is more volatile than zinc, is separated and recovered also. This pure zinc has made possible the production of a wide variety of familiar objects, e.g., carburetters, by the method known as die casting, and the cadmium has proved useful for rust-proofing steel.

Another chemical operation—fractional crystallisation—is involved in the process mostly used for separation of silver from lead. The lead is melted, zinc added, and the mixture cooled

somewhat. The zinc crystallises out first with some lead entangled, and very conveniently takes the silver with it when skimmed off as a crust, from which the zinc is distilled away and the silver recovered by the time-honoured operation of cupellation on which much chemical speculation was expended in the early days of the science. This operation of desilverisation has recently been made continuous, as a result of a very noteworthy Australian scientific research.

Electrolysis in aqueous solution is not the only method employed metallurgically. By using instead fused salts, some of the newer metals are obtained. Sir Humphrey Davy produced the first alkali metals, sodium and potassium in 1807; but it was many years later that the metal aluminium, now so extremely important, was produced commercially in similar manner. The process used was developed independently in France by Heroult and in America by Hall, the former a practical scientist and engineer, the latter a research student. The process, in essence, consists in dissolving purified aluminium oxide in fused mixed fluorides, and subjecting the mixture to electrolysis. Molten aluminium separates, and moreover is now very ingeniously electro-refined, using impure fluid aluminium as anode, and the pure metal as cathode, separated by a bath of intermediate specific gravity.

Magnesium, lighter even than aluminium, is obtained in a somewhat similar manner by a method devised by the great chemist Bunsen. How much these two metals have influenced modern aerial transport is widely appreciated, and though, of course, still much less than that of aluminium, the annual production of magnesium is rapidly increasing. It is used in the alloys " Elektron," " Dowmetal," and so on. (See Table II.).

While dealing with electro-metallurgy, the work of the eminent French scientist Moissan cannot be overlooked. By using the electric arc as source of heat, he was able to effect the reduction of oxides of certain metals which it had hitherto been impossible, or very difficult to reduce.

This led to the modern production of ferro-alloys and electric methods of steel melting. More recently we have the induction methods of melting steel suggested by Ferranti and only a few years ago metallurgy became indebted to another physicist—Northrup—for the " high frequency " furnace in which even platinum can readily be melted and which in its latest development provides probably the best method of melting high quality steel in lots of several tons at a time.

And so the catalogue of metallurgical development from chemical and physical research continues to lengthen, but time is too short to mention more. I will risk wearying you by mentioning but one further example. But before doing so, a brief digression may be made to indicate what is being done metallurgically in South Africa. Naturally, gold production and refining will occur to everyone, though it is not generally realised

TABLE II.

COMPARATIVE PROPERTIES OF STRUCTURAL METALS.

Metal	Condition	Specific gravity	Tensile strength, lb. per sq inch	Yield strength, lb. per sq. inch	Fatigue-endurance limit, lb. per sq. in.	Specific* tensile strength	Specific* yield strength	Specific* fatigue-endurance limit
Dowmetal H ...	Cast, heat-treated and aged	1·83	40,000	20,000	10,000	21,800	10,900	5,500
Al-Cu Alloy (S.A.E. 38). ...	Cast, heat-treated and aged	2·77	36,000	22,000	6,000	13,000	7,900	2,200
Grey Cast Iron ...	Cast	7·2	25,000	—	9,000	3,500	—	1,300
Dowmetal J ...	Extruded rod ...	1·80	43,000	30,000	17,000	23,900	16,700	9,500
Duralumin ...	Rolled rod	2·79	60,000	36,000	15,000	21,500	12,900	5,400
Mild Steel ...	Rolled rod	7·85	60,000	36,000	35,000	7,600	4,600	4,500
Cr-Mo Steel ...	Rolled rod	7·85	125,000	90,000	70,000	15,900	11,500	8,900

* The specific tensile strength, specific yield strength, and specific fatigue-endurance limit are equal to the tensile strength, yield strength, and fatigue-endurance limit respectively in pounds per square inch divided by the specific gravity.

Modern Uses of Non Ferrous Metals. (Am.Inst.M.E.).

that a small amount of silver is a regular by-product of the gold industry. Iron and steel is now well established, and provides the raw material for numerous subsidiary engineering and manufacturing industries. When writing a report in support of the establishment of the industry in 1918, I hardly dared visualise the production of such things as wire, galvanised " iron " sheets and steel tubes, yet all are now in regular production in addition to rails of the heaviest section and structural steel and mining drills. The smelting of copper has been in progress for a number of years, and ferro-manganese also is now produced, but that with some platinum and a little lead exhausts the list in the Union.

Our northern neighbours produce zinc as well as copper, and with imported materials from there and oversea, the Union is able to manufacture a wide range of alloys.

Technical training in mining and metallurgy is provided at the University of the Witwatersrand, which now has in point of numbers perhaps the largest School of Mines in the British Commonwealth. Chemical and physical science naturally provides the groundwork of the curriculum. From what has been said, it will be evident that it is the function of the metallurgist to take over his raw material, ore, from the miner and prepare it for the engineer, for whom in turn, manufactured metals are raw material. Miners and engineers are both, in consequence, given in a four year course, instruction in the branches of metallurgy with which they are more nearly concerned, the metallurgists alone covering the whole field.

But since the raw material of metallurgy is mineral, I must also refer to the Minerals Research Laboratory, which was recently established, and is maintained by means of a Government Mines Department Grant to the University, for the purpose of assisting in the development and utilisation of the mineral resources of the Union (excepting fuels) and which, of course, includes the treatment of metallic minerals. As well as the usual machines, furnaces and other appliances for ore treatment and analytical work, the equipment necessarily includes a wide range of scientific instruments of precision, e.g., microscopes, pyrometers, spectroscopes, and X-ray crystal analysis apparatus. And in addition to the staff of six trained research officers, four research scholars, financed by the Research Grant Board, are at work on various problems. These include *inter alia* methods of treatment for gold, platinum, chrome, tin and titaniferous iron ores.

Now in conclusion, we come to an example, which, whether we realise it or not, very closely affects the material well-being of every one of us here present to-night.

When gold milling commenced on the Witwatersrand, the method followed, as elsewhere, consisted in crushing the rock to liberate the gold and then passing it mixed with water over amalgamated plates or other devices in which the high specific

gravity of the gold was taken advantage of to cause it to settle and be caught.

The proportion so extracted varied according to the fineness of crushing and other circumstances, but seldom exceeded about 70 per cent., and the remaining 25 or 30 per cent. escaped in the tailing. Now working costs, roughly speaking, may be taken as 20s. per ton, represented at the present enhanced price of gold by about 3 dwt., so that 4½ dwt. ore would be required merely to pay expenses. A glance at the figures relating to the value of ore reserves of Rand mines shows that relatively few of them could make profits under these conditions, and in fact the position as early as 1890 was precarious in the extreme, although much richer ore was then worked.

Dr. Alder Wright, a chemist of Birmingham, had discovered that gold was soluble in cyanide solution in 1840. This received no practical application, however, and the discovery was apparently lost sight of; but in Glasgow, a chemist, J. S. MacArthur, in 1885 commenced a systematic investigation with the object of finding a chemical solvent which could be employed for the extraction of gold from ores. Many were tried, but it was nearly two years later that his experiments were successful with cyanide solution.

In 1890, the new process was demonstrated on the Witwatersrand, and showed such improvement in metallurgical results that it was immediately adopted, with the ultimate result that extractions of over 95 per cent. are now common.

This extra 25 per cent.—representing say 1½ dwt.—enables very satisfactory profits to be realised, and in short has made possible the growth to its present status of the Rand Mining Industry, which spends about £5,000,000 per month on wages and supplies, besides contributing directly several million pounds per annum to the Government exchequer.

You will be interested to learn, I am sure, that the memory of J. S. MacArthur and his associates, the Forrest brothers, is at last to be honoured on the Rand by the foundation of a Research Fellowship by one of our sister societies, the Chemical, Metallurgical and Mining Society of South Africa.

On this note I shall close. The more recent triumphs of metallurgy have, it is true, resulted from the deliberate application of scientific principles to practical needs, but these scientific principles were largely discovered and formulated as a result of research in pure science pursued simply for the sake of increasing the sum of human knowledge and largely without any immediate practical application in view. Obviously the debt of metallurgy to pure science is immense, and the encouragement of further research not only acknowledges the debt but expresses gratitude—not purely altruistic in motive either, but with a due appreciation of the possibility of benefits to come!

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THE BIRTH, GROWTH AND FUTURE STABILITY OF THE GOLD MINING INDUSTRY

BY

R. Craib.

Presidential Address to Section A, delivered 3 July, 1939.

I wish to thank you for the honour you have conferred on me by electing me President for Section A. The only duty which this appointment entails, so far as I know, is that a Presidential Address must be presented at the annual general meeting of the Association.

The selection of a suitable address usually presents a problem of some difficulty, but on this occasion I have not found it so, because I feel sure it will be expected of me to deal with a subject to which I have devoted the greater part of my professional career, which has been mechanical and electrical engineering in the Gold Mining Industry of the Witwatersrand. Furthermore, I feel that a Presidential Address need not be confined to some single engineering problem which would be of interest to only a few, but rather to devote the time at one's disposal to a general description, which would probably be of interest to the majority and induce others to take an interest in the various subjects brought under review.

The theme of my address will therefore be " The past history and probable age of the deposition of the sedimentary beds of the Rand, the present method of mining the conglomerate reefs found in the sedimentary rocks and the future possible activities of the mining industry." The address has been sub-divided into two main sections (a) Geology and (b) Mining.

In the geological section I propose to develop a new theory regarding the reason for the great climatic changes which are known to have occurred in the past history of the earth and which, no doubt, were in part at least responsible for the laying down of the auriferous rocks of the Rand.

In the mining section I propose to outline a new system of mine layout and organisation to extract deep-lying ore by technical means at present available.

Geology.

The sedimentary deposit, known as " The Witwatersrand System," lies immediately on the surface of the granite and reaches, according to Dr. E. T. Mellor, one of our past Presidents, to a depth of twenty-five thousand feet below the present surface

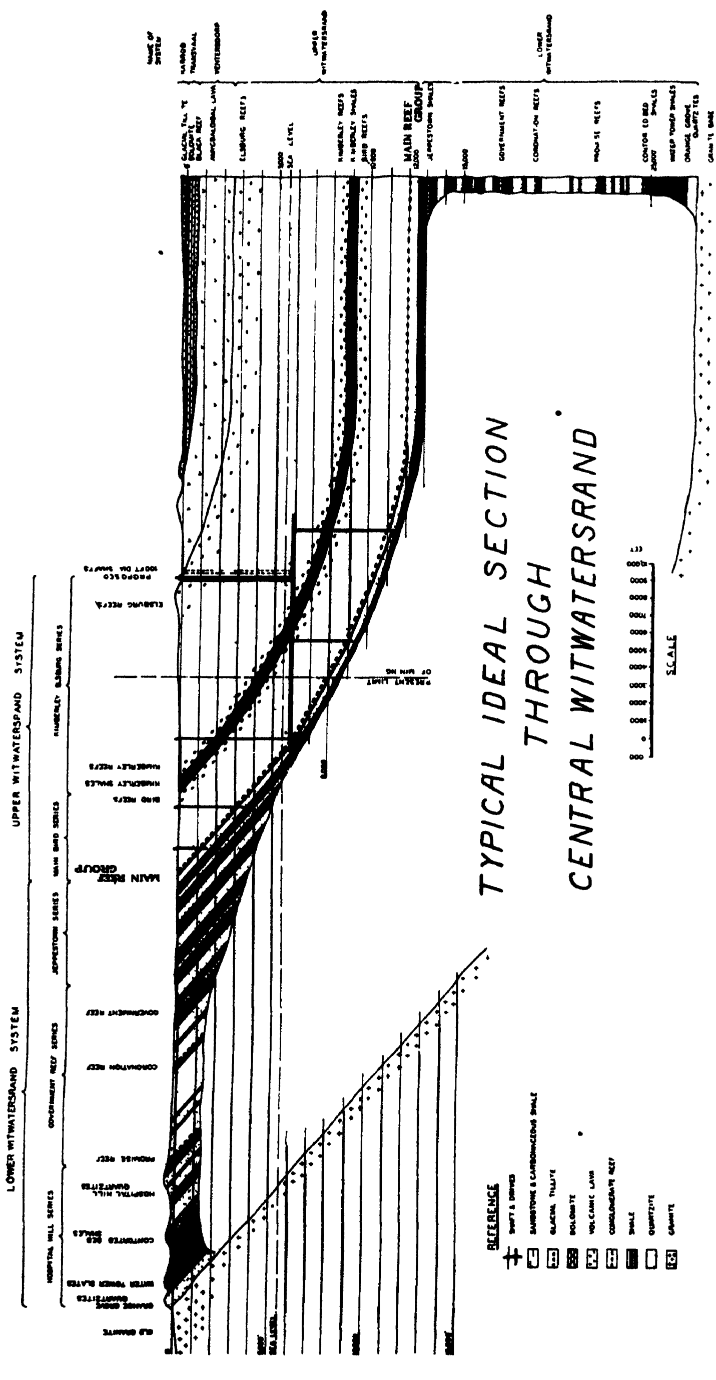
TYPICAL IDEAL SECTION
THROUGH
CENTRAL WITWATERSRAND
UPPER WITWATERSRAND SYSTEM
LOWER WITWATERSRAND SYSTEM
MAIN REEF GROUP
SCALE
REFERENCE

Fig 1.

in certain places. The strata consist of beds of sand, clay and layers of conglomerates which have, through course of time, been formed into a homogeneous mass of rock. The layers vary in order and in thickness and have been derived from an unknown source. There have been no fossil remains found in the sediments and therefore they are of an unknown geological age, but are undoubtedly among the oldest rocks known. The conglomerates are composed of water-worn quartz pebbles, embedded in a matrix of silicious cement containing iron pyrites.

Not all of the numerous conglomerate beds are an economic mining proposition, although all contain a certain percentage of gold. The three reefs which have been mostly mined are named the "Main Reef," the "Main Reef Leader" and the "South Reef." They are situated near the middle of the sediments of the "Witwatersrand System," just discussed (see Fig. 1).

The conglomerate beds of the Main Reef Series might never have been discovered, had it not been for another of Nature's phenomenon, in elevating the granite floor on which the selimentary deposit was placed. It so happens that the elevation of the granite has titled the fringe of the strata to an angle of approximately 35° to 80° in the Central Witwatersrand area and 14° in the south-eastern corner. The tilting of the strata, in conjunction with denudation, has exposed the formation over a large area, but even so, it is a moot point whether the early prospectors would have realized the importance of the gold bearing reefs, had it not been for the secondary enrichment, caused by denudation between the time of tilting and the advent of man.

With regard to the gold content of the various reefs, I only propose to refer to it in the briefest possible manner. In all probability the method by which the gold was introduced was by the same natural cause as is in progress in different parts of the world at the present time. An intrusive quartz vein carrying gold intersects the country rock and, in course of time, on account of disintegration and erosion, the whole is transported by means of water to lower levels. The softer rocks being more easily crushed are carried away in the shape of mud or clay, whilst the harder rocks, having a greater resistance to abrasion, travel along more slowly in the shape of water-worn pebbles and sand. The heavier materials, of course, gravitate to the bottom and are not dislodged until the climatic conditions are favourable. Under mild climatic conditions the mud and clays are transferred to a fresh position, such as a lake or ocean bed where the velocity of the water is gradually brought to rest and the deposition of the suspended matter takes place. Under more severe weather conditions the sands and grits are transported whilst, of course, with torrential floods, the pebbles and heavier materials are the last to be moved. Such was in all probability, the method of formation of the sedimentary layers of shales, sandstones and conglomerates as found on the Witwatersrand.

The climatic conditions of South Africa during the deposition period were, of course, entirely different to those of the present time. Large rivers, which the country does not now possess, were required for the shaping and transportation of the materials and, also, the Witwatersrand, which is now an elevated plateau of approximately six thousand feet in height, must have been, at the time of deposition, on a level with the sea, because the clearly defined layers of deposit and the accurate grading of pebbles could only have been accomplished through an agency such as the sea, with which we are conversant.

There is a glacial evidence to prove that South Africa was once under an ice sheet and, I have no doubt, that the sedimentary deposits of the Rand were laid down sometime before or after the land had emerged from under the Antarctic ice cap. In this position the high veld of South Africa would probably have been on a level with the sea, large rivers would have been flowing and the climatic conditions would have been favourable for the deposition of the "Witwatersrand System." If this assumption is correct, then it is possible to arrive at an approximate date on which the foundation of the gold mining industry was laid, if we know the number of years it has taken South Africa to traverse the distance between the polar region and its present position.

This now brings us to the old controversial subject "Ice Ages and Their Birth." There have been many theories advanced to account for ice ages, but it is evident that no single theory is generally accepted and, indeed, difficulties have been raised against all of them. However, I am of opinion that if we accept the conditions pertaining to the earth's surface at the present time and adjust our assumption to those conditions, we shall arrive much closer to the truth of what has happened in the past than if we accept some conjectural opinion for which there is no visible foundation.

There are on the earth's surface at the present day only two ice sheets of continental dimensions, one situated at the North Polar region and the other at the South. There are, of course, a number of smaller ice caps which generally occupy high plateaux, but, as they are of minute dimensions compared to the ice sheets under discussion, they need not be taken further into consideration.

The earth revolves on an axis, the northern end of which points, with slight variations, to a certain part of the celestial sphere. During the course of five thousand years, this pointer has described the arc of a circle which, it is calculated, will complete the circle in twenty-five thousand eight hundred years. Those are the only two facts, i.e. the present position of the two ice caps and the circle described by the northern or southern axis of the earth on the celestial sphere, we have to depend on for the solution of the problem to account for the glaciation of separate sections of the earth's surface at different periods.

There is no justification for the assumption that the observed changes in latitude of fixed observatories and the annual retrogression of the equinoctial point on the equator is due entirely to a movement of the earth's axis of rotation in relation to the plane of the ecliptic as is shown in Fig. 3.

While there is undoubtedly some motion of this axis of rotation relative to the ecliptic, I maintain that part of the observed motion is due to a bodily movement of the outer crust or lithosphere relative to the plastic inner core or barysphere (Fig. 2).

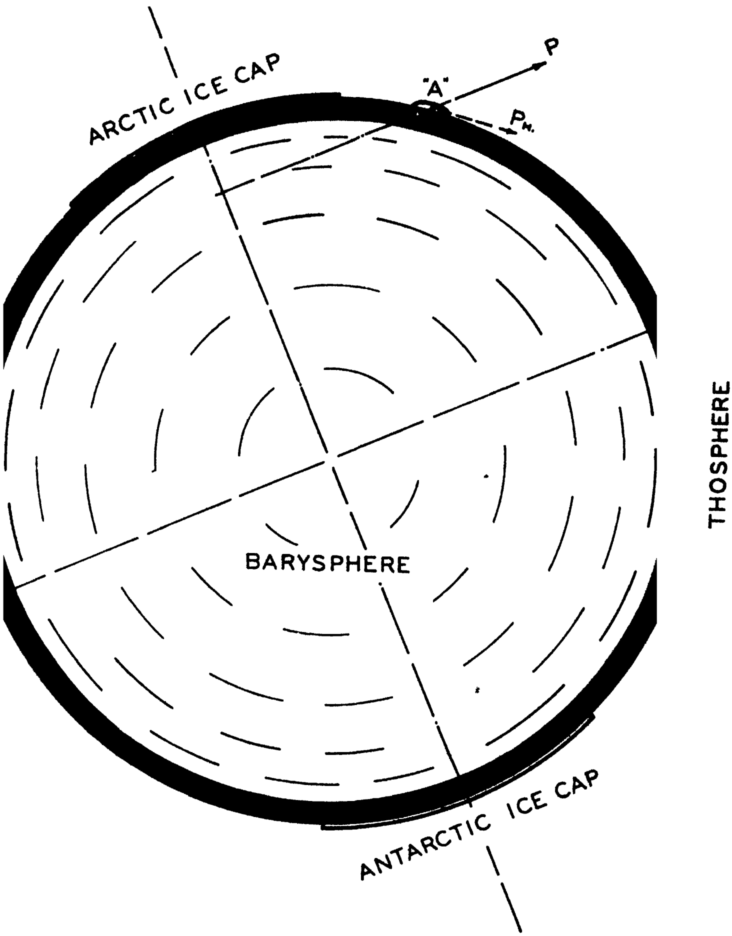

Fig. 2.—Terrestrial Forces tending to produce Sliding of the Lithosphere.

This motion would cause the lithosphere to slide under and eventually emerge from a comparatively stationary polar ice cap. Therefore, instead of speaking of the retreat of an ice sheet, the

phrase should be "The emergence of the earth, i.e. the lithosphere, from under the polar ice caps." There is no other explanation because, if it is assumed that there is no movement of the lithosphere, then an explanation must be given to account for the necessary depletion of the lithosphere and the mountains of debris which would have been produced by the polar ice sheets during the lengthy period of time the work accomplished by the ice sheets has been in progress.

The flattening of the earth at the poles conforms in all respects to the law of dynamics. This may be confirmed by designing a hollow steel sphere, having an outside diameter of eight inches and the shell one-quarter of an inch in thickness which would represent the lithosphere of the earth on a scale of one inch to one thousand miles. If this sphere is revolved at a maximum peripheral speed of fifteen hundred and twenty feet per second, which is the peripheral speed of the earth at the

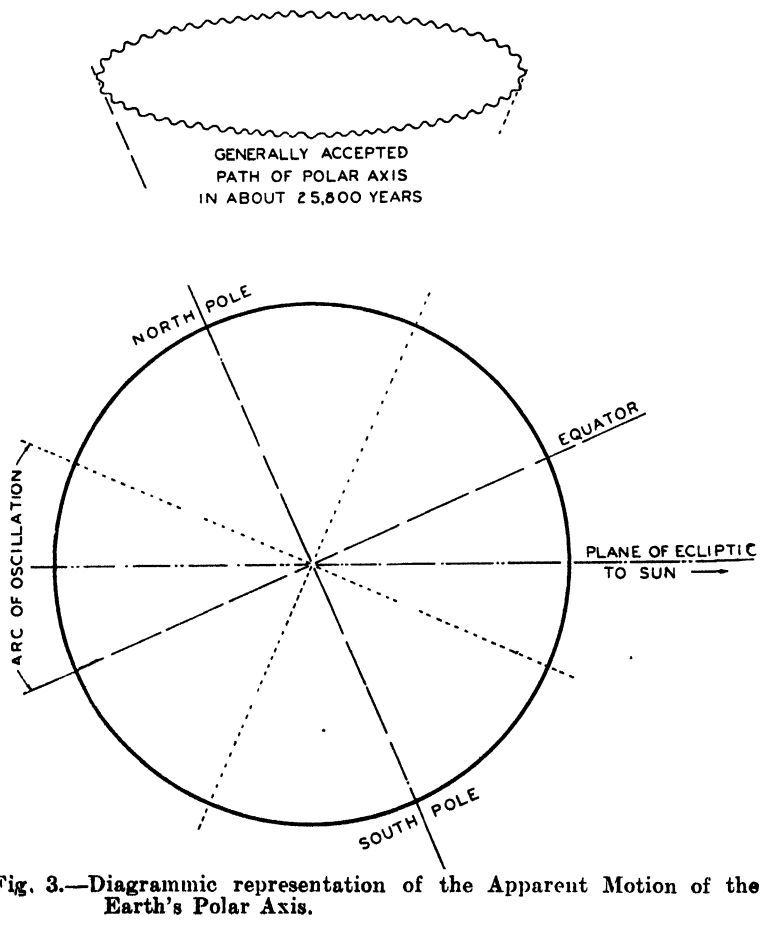

Fig. 3.—Diagrammic representation of the Apparent Motion of the Earth's Polar Axis.

equator, it will be found that the polar diameter will be decreased by 0·021 inches, which is equal to the earth's polar decrease in diameter of twenty-seven miles and shews that both are of the same order of magnitude. Great care would have to be exercised when trying this experiment because, even with a shell made from steel having a tensile strength of one hundred and thirty tons per square inch, there would be danger of fracture at this phenomenal speed, with disastrous results to the experimenter. The thickness of the lithosphere is assumed, by various authors, at anything from forty to four hundred miles, but for other reasons which are too controversial for the present address, I am inclined to the opinion that a thickness of two hundred and fifty miles is probably the correct figure.

The greatest amount of materials transported from place to place by natural means on the earth's surface is undoubtedly done at the equator and, as it is unlikely that such transportation is done evenly round the earth, it is obvious that any change of the land surface would set up vibration to an enormous extent, were it not for the hydrosphere which accommodates itself to the altered condition and permits of the earth revolving in a nearly perfect balanced state.

The case is altered entirely, however, when transportation takes place in any position between the equator and the polar regions for, in this case, it is unlikely that the displaced material is evenly distributed round the pole and we may therefore suppose that in a given period a resultant unbalanced mass accumulates, such as " A " in Fig. 2.

Due to the rotation of the earth, a centrifugal force shewn as " P " in Fig. 2, is continually acting on the unbalanced mass " A." One of the components of this force is a horizontal force " P_h " acting tangentially to the lithosphere and unless it is opposed by other forces of equal magnitude it will cause the lithosphere to slide over the barysphere.

As already explained, I am of the opinion that the observed variations are not all due to motion of the barysphere's axis of rotation and, therefore, there is only one conclusion to which one can arrive, which is that the lithosphere is slowly but constantly changing its position in relation to the central core. This movement explains many of the phenomena in connection with glaciation and some in connection with sunken continents, mountain raising, faults, intrusions and earthquakes, because, during its slow spiral movement between the poles and the equator, covering in arc of ninety degrees, the lithosphere would expand and contract thirteen and a half miles whilst the figuration of the hydrosphere would, of course, remain constant.

It is well known that, according to present theories, the earth is considered to behave like an unstable spinning top and that, therefore, its polar axis of rotation does not remain stationary but that its projection on the celestial sphere appears to describe a wavy circular path (see Fig. 3).

This phenomenon is known as " Precession " and is due to an oscillatory motion of the earth's equatorial plane about the plane of the Ecliptic produced by the attraction of the sun and moon upon the earth's equatorial bulge. One complete oscillation takes about 25,800 years, that is, the polar axis takes this period of time to describe the wavy circle on the celestial sphere.

Precession is principally due to the sun's attraction of the equatorial bulge; by itself this would cause the pole to describe a plain circle, but slight modifications of this motion known as " Nutation " make the path wavy instead of plain. This is produced by the attraction principally of the moon and to a very minor extent to a variation in the sun's attraction owing to the varying distance between the earth and the sun and also, possibly, to the attraction of the planets.

In addition to this motion of the polar axis, there is another displacement of about 46 seconds of arc per century which has been thought also to be of an oscillatory nature over a period of 10,000 years.

All these motions of the polar axis are, of course, based upon a theoretical analysis of the deduced complicated motion of this axis over a comparatively short period of time (at most, 5,000 years). It is quite possible that all these movements may not be oscillations through small arcs, some may be very slow continuous motions or else oscillations through very large arcs because it has been obviously impossible to observe a complete cycle of the polar axis motion described on the celestial sphere.

If this conception is coupled with the idea previously expounded, namely, that the lithosphere slides over the barysphere, then it is possible to postulate that any portion of the earth's surface could, at one time or another, have been covered by a polar ice sheet.

The position briefly then is this. We live and conduct our astronomical and terrestial observations upon a thin crust (the lithosphere) which is capable of sliding over a plastic inner core (the barysphere).

Due to the agency of external forces supplied by the sun, moon and probably planets, the lithosphere, and to a certain extent the barysphere, is subjected to a complex oscillation, during a period of nearly 26,000 years. This oscillation is strongly modified by the eccentric forces resulting from dynamically unbalanced products of topographical erosion, especially in high latitudes particularly at the margin of the polar ice sheets, which tend to produce a bodily movement of the lithosphere from the poles to the equator.

If we take the motion of 46 seconds of arc per century as the principal one which has not been adequately explained and assume that one-third of it, or 0·155 seconds of arc per annum, is a continuous and not an oscillatory motion, then we are in a position to calculate the minimum time in which it is possible

for a point on the earth's crust to move from one place to another in relation to the interior core.

For example, the Witwatersrand is removed from the Antarctic ice cap by roughy 55° of latitude. To traverse this distance at the rate of 0·155″ per annum would therefore take one and a quarter million years, if the path were straight or due north throughout. If it was sinuous, as it most probably was, this time would have to be very considerably increased. No upper limit could, accordingly, be fixed, but the lower limit would be as stated.

From the above calculation, it would appear that the surface portion of the lithosphere, which is now known as the Witwatersrand, was meandering under ideal surroundings and favourable conditions for the deposition of the sedimentary layers, in the vicinity of the antarctic region, some 1¼ million years ago. There is, however, indisputable geological evidence to prove that the Witwatersrand system was laid down prior to the last glacial age in this country and, therefore, it may be assumed that deposition took place before the country moved under the polar ice cap, which would increase the above figure considerably.

This theory, I have no doubt, will be questioned but an endeavour has been made to shew from the laws of dynamics that there are available stupendous forces, which account for many of the big known changes in the earth's climate and geological structure.

Gold was known to exist in the conglomerate beds of the Rand in 1845, but it was not until the year 1884 that serious thought was given for its extraction. From that time to the present day the mining industry has progressed to an extent that it now finds itself in the eminent position of being the world's premier gold producer. To maintain this status it has been necessary to develop a technique which is known and appreciated throughout the mining world.

Every conceivable device known to science has been requisitioned for the efficient and safe working of the mines and whether it is in mining, hoisting, pumping, reduction of ore, care of employees or first aid to the wounded, it will be found that each department is in charge of a highly skilled official who has specialised in his own particular branch of science.

The growth of the gold mining industry will become apparent on perusal of the following figures which give the tonnages crushed and the ounces of fine gold recovered, in three different years during the life of the industry:—

Year		Tons Milled.		Fine Gold Recovered. Ozs.
1893	...	2,215,413	...	1,221,171
1915	. .	28,314,579	...	8,772,919
1938	...	53,834,150	...	11,839,077

To maintain an output of 54,000,000 tons per annum it is necessary, each working day, to lower below the surface to a average depth of 4,000 feet some 20,000 Europeans and 230,000 Natives, who all have their own particular task to perform. Some may be employed in the support of workings, others in shoveling ore, tramming, reclamation, drilling holes for explosives and numerous other duties which must be completed before they are again raised to the surface.

The mining tool of to-day is the " Jack-hammer," which is light enough to be held in the hand of the operator and may be used effectively under practically every condition previously met by hand drilling. If we exclude shaft sinking, development and other necessary requirements, it will be found that probably 5,000 rock drills are in daily use, for the purpose of drilling sufficient holes to accommodate the necessary quantity of explosives to break 200,000 tons of rock, which is the daily quota required to maintain the above annual output. The aggregate of one day's drilling equals 108 miles and the consumption of steel in this performance amounts to approximately twenty tons.

Unfortunately, time does not permit of a longer description of the present day activities of the industry, but sufficient has been given to shew that it is the largest of its kind which has ever been known.

The two most important factors by which the future of the gold mining industry is governed, in my opinion, is that of taxation and ventilation. The present price of gold has made it possible to mine a limited quantity of ore from depths of eight thousand feet, but the margin of profit left over after having met all commitments, would be inadequate to encourage the investor or to make provision for the future in extending the area already being mined.

In course of time, several of the producing mines will have closed down and, therefore, if the present-day standard of gold production is going to be maintained, it will be necessary to seriously consider the economic possibilities of mining at ultra deep mining depths.

The unique position and continuity of the auriferous layers in the sedimentary beds of the Rand makes the solution of the problem of ultra deep mining possible, provided the investing public is given adequate assurance that the only possibility of losing capital will be due to no other cause than that of the usual mining venture. This is all I have to say in connection with taxation because, although I would have preferred not to have mentioned the subject in the present address, it is so interwoven with the future development of the industry that attention should be drawn to the fact, that a large capital expenditure, and five or six years preparation is necessary to bring a moderately deep mine to the producing stage. With ultra deep mining, of course, both expenditure and time for production become infinitely greater.

The question of taxation having been satisfactorily settled, as I feel sure it will be, there remains the other important factor of ventilation. It is true that there are many other difficulties to be faced when mining at great depths, such as pressure, hardness of rock for drilling, hoisting and probably the most important of all, the daily quota of heat liberated during blasting operations on account of the higher rock temperatures. All these obstacles, however, will be faced and surmounted with the same measure of success in the future as they have been in the past.

The generally accepted temperature increase with depth is 1 degree F. for every sixty or seventy feet but, on account of the elevated land surface of the Witwatersrand, the temperature increase is not nearly so high as this figure and is actually found in practice to be in the neighbourhood of 1 degree F. for every two hundred and thirty-three feet. This figure would indicate a rock temperature of 117 degrees F. when mining at a depth of twelve thousand feet, but this feature of the problem need not be taken seriously because, with adequate ventilation, the rock temperatures encountered would not be greater than that experienced when mining at a depth of six thousand feet below the level of the sea, which is the natural horizon for the existence of mankind.

Most, if not all, of the deep level producing mines on the Rand, are an extension of what was known in the early days as out-crop propositions. The shafts which were sunk at that time were suitable for the requirements of the mine, but as the depth and temperature increased, so the conditions altered, and this led to the serious problem of ventilation. Shafts of larger dimensions were sunk and large sums of money have been spent on mechanical appliances for the purpose of improving the ventilation system and although a certain amount of success has been achieved, the system would be unsuitable for ultra deep mining.

It will be obvious to all, that if it were economically possible to mine from open workings, there would be no ventilation problem and, therefore, the only solution to the problem of ventilation when mining at great depths, is to provide adequate shaft capacity.

The capital outlay necessary to bring a modern Witwatersrand gold mine to the production stage is anything between three and four million pounds and it takes five to six years before the mine will commence producing. This is assuming, of course, that the reef is in the neighbourhood of five thousand feet below the surface. With depths greater than this, the capital outlay would be much greater, and indeed, it is questionable if the present system of opening up new mines would be an economic proposition.

The unmined portion of the main-reef series and the value of the ore content is of course unknown, but, from present indications it would appear that there is yet an area of unmined reef,

considerably greater than that which has already been mined and is in course of being mined at the present time. Unfortunately, however, the major portion of the reef underlying this area is situated at a depth of probably twelve thousand feet and to acquire more accurate information in connection with depth and value, it would be necessary to advance two cross-cuts from existing mines, into the hanging-wall country at a depth of six or seven thousand feet below the surface and drill a borehole from the end of each cross-cut to explore the formation and the probable reef position.

This method of proving the continuation, value and depth of the main-reef series would entail a large expenditure of approximately £500,000 but would amply repay the outlay in providing valuable information for the design of hoisting equipment and the layout of future mines.

My confidence in the continuation of the main-reef series, however, is such, that the following collective method of transporting ore and ensuring adequate ventilation when mining at ultra deep depths has been prepared. It must be apparent to all engineers that the present method of hoisting ore through the inadequate shafts which are in use to-day, would be both uneconomical and impracticable for the large tonnages which must be drawn from depth considerably below six thousand feet.

Without some vastly improved arrangement it will be economically impossible to mine the whole of the auriferous conglomerate and this will decrease the life of the industry to a much greater extent than is generally supposed. It must be borne in mind, however, that with the engineering technique already acquired, encouragement and sound financial backing, there is no reason why the gold mining industry should not continue to flourish as at present for several generations.

I have given this matter serious consideration for several years and I am satisfied that the solution of the problem of ultra deep mining, rests in the provision of a subsidiary outcrop, at approximately six thousand feet below the surface, and from which elevation a staggered line of vertical shafts would be sunk for the purpose of serving a number of mines.

For the purpose of calculating the economic possibilities of ultra deep mining, it will be necessary to assume a number of mines which may be termed a unit. The unit will contain six mines, each of which will have a claim area, equal in extent to five thousand claims, and the unit will be served by six circular shafts of one hundred feet in diameter. The method employed at the present time for opening up deep mines of from three to six thousand feet below the surface, is to sink two vertical shafts and as mining progresses sink further verticals from the surface until, eventually, there are five vertical shafts serving a mine with an area of five thousand claims.

It will be found as we proceed, however, that six shafts of the above dimensions will give more efficient service, provide adequate ventilation and will cost, in the aggregate, no more than the smaller dimensioned shafts in use at the present time. It would, of course, be impossible to control the unit, or six mines, by the same personnel as is in vogue to-day and, therefore, it will be necessary to divide the company controlling the unit into four companies of smaller dimensions. One company will be responsible for the transport of men, material and ore from the six thousand foot level to the surface. Another company will supply the compressed air and control the drainage system, whilst the third company will control the mining section below the six thousand foot level and the fourth company will be responsible for the reduction of the ore produced. Electric power would, of course, constitute another company, but as there is at present an efficient power supply company in existence and which is quite capable of taking charge of the position, it is unnecessary to again refer to the subject.

The capital requirements of the four companies to complete a unit would be approximately as follows:—

Transportation between the 6,000 foot level and Surface Reduction Works	£7,000,000
Shaft Sinking, Equipment and Development below the 6,000 foot level	7,000,000
Drainage, Ventilation and Air Power	5,000,000
Reduction Plant	6,000,000
Contingencies	5,000,000
Total	£30,000,000

The above figures would represent a capital outlay of £5,000,000 for each of the six mines, a figure which does not appear unreasonable.

The transport company would be responsible for the sinking of six circular shafts to the 6,000 feet horizon and connecting them by means of a large haulage. The necessary equipment would include six super winding engines, each capable of hoisting a rock load of sixteen tons at a speed of 4,000 feet per minute and six smaller winding engines suitable for the conveyance of men and materials.

Headgears, locomotives and track are also included in the equipment, but, fifty per cent. of the cost of sinking the shafts would be a debit against the drainage and ventilation company, as most of the shaft capacity is required for purely ventilation purposes.

Hoisting a load of eight tons from a depth of 6,000 feet has become a practice, and it is considered that under existing conditions this weight is about the maximum which should be

attempted. When mining at depths greater than 6,000 feet, however, and hoisting large tonnages. it is essential that both the winding speed and weight of load should be increased. This is possible, provided the depth of hoisting is not greater than approximately six thousand feet.

The factor which governs the weight of load to be hoisted is, of course, the strength, weight and necessary length of rope required and, in this case a suitable winding rope to hoist a pay load of sixteen tons from a depth of six thousand feet, will have a diameter of three inches, will weigh 15·21 lbs. per foot and will have a breaking strength of four hundred and fifty-five tons.

A rope of the above dimensions will support—with a factor of safety of six—its own length for a depth of ten thousand feet. Only six thousand feet are required for hoisting purposes and, therefore, there remains the equivalent weight of four thousand feet to be utilised for the weight of rock load and conveyance, which is approximately thirty tons.

A winding speed of four thousand feet per minute need not be considered excessive, and in all probability, a speed of five thousand feet per minute, when hoisting rock, could be attained. These speeds should be possible on account of the large shaft clearances whereby the air friction will be reduced to a minimum and, as the necessary shaft supports will be fabricated from reinforced concrete, the danger from dislocated timber in the shaft would be non-existent. The only timber which might be installed in the shaft would be for guides, if wood is used for this purpose in preference to steel.

The above winding problem has been described at probably greater length than is really necessary, but, as hoisting is a major issue in ultra deep mining, it is essential to establish that heavy loads can be raised at a much greater speed than that which is in general use to-day and this becomes necessary when hoisting large tonnages of rock from great depths.

It is unnecessary to refer to the size of the winding engine because, at the present time, rock loads of eight tons are being hoisted from a depth of over six thousand feet and, as the pick-up load in this case is merely doubled, the size of the engine must be proportionately increased.

Shaft sinking and development for the six mines will be commenced from the six thousand feet horizon, which may be termed the sub-outcrop, and. according to the position of the mine in relation to the dip of the auriferous layers, it will be necessary to drive two tunnels for each mine to a suitable position from which to commence mining operations. All expendture in connection with mining and equipment below, or from, the sub-outcrop will be a debit against the individual mine concerned and it will be the mines responsibility as well to provide the necessary surface requirements, such as compound, hospital, shops, houses and the recognised surface requirements.

There will be the usual number of shafts, through which the mine will deliver the ore produced to the sub-outcrop. These shafts and their equipment will be of much smaller dimensions than the surface shafts and their location will be what is considered to be most suited to the mining of the area concerned. The ore delivered on the sub-outcrop will be taken charge of by the transportaion company and conveyed to the surface reduction works.

The transportation company will also be responsible for the transport of men and materials and, during an average working day, will lower and raise from the six thousand foot level, something in the neighbourhood of fifty to sixty thousand natives as well as the European staff necessary to supervise this force. The equipment and organisation necessary for the transport of this large complement will be so arranged that the men will reach their stations with the same measure of ease and safety as they would do on any other underground transport system.

The underground water from each mine will be pumped to the sub-outcrop from which place it will be collected by the drainage company and delivered on the surface. With an adequate supply of electric power, compressed air and fresh water supplied to the individual mine by the drainage company, the risk of failure of the supplies will be remote and the miners' responsibilities will therefore be proportionally decreased.

The drainage, ventilation and compressed air supply company will collect all water on the sub-outcrop from the separate mines and pump it to the surface, where it will be distributed to the reduction works. It is difficult to estimate the quantity of water which will have to be pumped, but it is reasonable to assume that the natural inflow from each mine, plus the quantity of fresh water sent down for drinking, machines and other purposes, will not be much less than fifty million gallons per month, which will produce a figure of three hundred million, or ten million gallons every twenty-four hours. In all probability this large volume of water will not be encountered in the early stages of mining, but it is essential that adequate pumping plant should be installed to meet any emergency which may arise.

The necessary equipment to deal with quantities of water such as this, will require twelve centrifugal pumps, each having a capacity of one hundred thousand gallons per hour and designed for a static head of three thousand feet. In one of the central shafts it will be necessary to cut, whilst sinking, a suitable pumping station for the purpose of accommodating six of these units. This will provide the second lift of what is generally known as stage pumping.

For the purpose of supplying the six mines with ample fresh air, the six circular shafts will have a cross sectional area, after deducting 20 per cent. for obstructions, of 37,704 square feet.

Three of the shafts will be down cast and three others upcast and will be suitable for the supply of approximately 200 cubic feet of fresh air per minute for every underground employee.

Slightly more power than the natural heat will be required to keep the large volume of air in motion and it will be the function of the ventilation company to supply and maintain suitable apparatus for this purpose. It will also be the business of the company to provide each mine belonging to the unit with the necessary quantity of air required.

Three large reduction works, each having a crushing capacity of four hundred thousand tons per month will be required for the reduction of the ore produced by the unit. These works will be situated in different localities for the purpose of ensuring ample dumping space for the disposal of residues and waste rock. The selection of suitable sites will depend on the topographical features of the locality as the conservation of large volumes of water will be of primary importance.

The three reduction works will be divided into six sections, so that the ore from one mine will not become intermixed with the ore produced by one of the other mines belonging to the unit. This, of course, might be altered and a decision come to whereby the one reduction plant would deal with the entire output of the two mines concerned, with possible economies, if it is found possible to allocate equitably the gold output to the separate companies.

The system of milling large tonnages of ore from separate mines, will create a position by which it will be possible to eliminate most of the small but essential equipment, required in the present day reduction works, and will have the effect of still further increasing the already high standard of efficiency met with on the Rand.

My calculations which of necessity are only preliminary estimates, shews that approximately £30,000,000 is required to open up an area of this kind and the distribution of revenue from this scheme is shewn hereunder.

The yearly revenue derived from the sale of gold by the unit, assuming that the price of gold and demand remains as at present, will amount to approximately £20,000,000. Working costs will probably be in the neighbourhood of £15,000,000 practically all of which will be spent within the Union of South Africa. The interest on capital and redemption will amount to a further £4,500,000 leaving a small unexpended balance of £500,000, which is a very small margin to provide for unforeseen emergencies, to which all mining ventures throughout the world are subject to and will be especially so in an undertaking of the above magnitude.

The above figures must be considered purely as an estimate and are therefore liable to adjustment. They do show, however,

that ultra deep mining, excluding direct taxation, is both a practical and an economic proposition.

I have now reached the end of my address, but before concluding I should like to mention that an endeavour has been made to explain the most likely method by which the sedimentary deposits of the Rand were accumulated. There have been many theories advanced to account for their formation and I am not quite sure that I have been any more successful in finding a solution to the problem than other authors who have studied the subject, but, nevertheless, even unsatisfactory explanations may be of value, in so far that they direct attention to factors which may have been insufficiently studied and thus lead to research which may eventually increase our knowledge of the subject.

The hypothesis in connection with the possible age of the oldest sedimentary rocks and the solution of the problem by astronomical observations will, I feel sure, lead to much controversy. It must be remembered, however, that accurate information on a subject of this description is at present unobtainable and, therefore, if the suggested method of determining the age of rocks devoid of fossil remains is unacceptable, it will at least afford a sort of basis for further discussion, which may eventually lead to the true answer and, I hope, bring to those of our members and others a few pleasant hours of suggestive thought.

The section which deals with the future activities of the gold mining industry is, of course, of a more practical nature. It is common knowledge that the chief source of our national income is a wasting asset and, although a small income derived from secondary industries may assist this wastage to a limited extent, it must be borne in mind that in a sparsely populated country such as ours, the demand for manufactured goods will be of a negligible quantity if the Primary industry of the Witwatersrand is allowed to wane.

There are no insurmountable difficulties of which I am aware to prevent mining at depths suitable for the recovery of the whole of the auriferous conglomerate layers associated with the "Main Reef Series" and, therefore, any information or other suggestions which will tend to confirm this assurance will be to the mutual benefit of the whole of the Union of South Africa.

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SOUTH AFRICA AND NUTRITION

BY

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Presidential Address to Section B, delivered 4 July, 1939.

Introduction.

Someone has remarked that nutrition, whilst the youngest of the sciences is the oldest of the arts. But even the deliberate study of nutrition is hardly as youthful a subject as many imagine. The Chinese scientist Hou tells us that one Shen Nung was busy writing about dietetics as long ago as 3000 B.C. and during the Chou dynasty, about 1155 B.C. there even appears to have been a department of dietetics established, which, as was fitting, ranked first in the medical organisation of the State!

Towards the end of the nineteenth century the art slowly began to take on the semblance of a science, chiefly owing to the development of physiology and chemistry, which have gradually enabled us to penetrate some of the mysteries concerning the nature of the foods we eat and what happens to them during the course of their metabolism in the body. These developments received little attention from the general public until quite recently when there has been a rapid and widespread awakening of public interest, partly owing to the sensational nature of the developments that have been taking place and also no doubt to the skilful way in which each development has been exploited by the great commercial interests concerned in the food industry.

But another reason for this growing interest in diet has been a gradual awakening to the fact that human beings are undergoing certain physical changes of a most interesting kind. Thus the Englishman's average length of life increased from 41 to 55·6 years between the 1870's and 1920 and has since increased still further. There have been similar striking increases in stature in many European countries. In Sweden, from 1840 to 1926, the average stature increased by over three inches; in Denmark the same increase took place betwen 1840 and 1913; in Norway the increase was four inches between 1800 and 1900 and in the Netherlands about five inches between 1850 and 1907. A similar phenomenon has been observed amongst both male and female students at several American universities. Stature is but one of

several other physical characteristics that have been undergoing changes within the last hundred years.

These alterations in physique, in expectation of life and in vitality that are attracting the attention of observant people are not due to chance, but result from improvements in economic welfare, sanitation, medical knowledge and in diet; thus there has been an improvement both on the " positive " side in building up health, physique and resistance against illness and also on the more " negative " side in controlling and preventing disease. That diet alone can play an important part in such adjustments has now been conclusively proved from the study of both animals and children.

A history of dietetics would also take note of the really surprising number of changes that have taken place in comparatively recent times regarding the quality, variety, transport and storage of the food we are eating. Better varieties, better methods of cultivation, grading and inspection have led to remarkable improvements in the size and flavour of the vegetables and fruits that are now normally available. Many can remember when such fruits as the tomato, banana, grape-fruit, avocado pear and loganberry were far from common, at any rate in England, whilst to-day we are beginning to make the acquaintance of new hybrids which may in their turn find wide popularity. Owing to improved transport, which has literally annihilated distance, a community is no longer restricted to the products of the immediate vicinity, but often draws on the whole world, even for its daily food; moreover, transport is tending to obliterate the seasonal factor, so that, for instance, oranges and apples are becoming freely available in many countries almost all the year round. Improved methods of preparing and storing foods have also exerted a very marked effect upon diet; processes such as the pasteurization, condensation and evaporation of milk have made it safer as well as more transportable, with very little loss of original nutritional value. The canning and bottling of other foods have made them available in countless homes where otherwise they could never have been consumed, whilst the quality of these products has improved to such an extent that in many cases even the antiscorbutic activity is well maintained. The remarkable development of cold storage methods, by means of which the exacting requirements of many different types of food are most satisfactorily met enables fish to be sent from Capetown to the Congo, crisp salads to be available on ocean liners when far out at sea and stocks of butter to be stored and released according to market conditions.

As might be expected, however, there is also a less satisfactory side to some of these developments. We all know about the over-refinement of bread, which was originally due to the desire to improve its keeping properties as well as its colour, the invention of a host of " patent " foods, " health " foods and the

like; the adulteration of foods with every imaginable substance, until adulteration and the detection of adulteration has developed into a battle of chemical wits.

Then there is the wholesale exploitation of public credulity regarding the vitamins, mineral salts and so on. Less obvious, but to be regretted, has been the decline in skill and resourcefulness of the average housewife, who can now with little time and less trouble produce a meal of standard quality but standard dullness from the contents of a few tins, as compared with former days when bottling and preserving was an art in which the more enterprising could show their skill and delight their friends. It might be well to mention, too, that the ubiquitous refrigerator is not without its dangers for putrefactive changes are sometimes masked rather than inhibited by low temperatures.

As a consequence of these developments in the food industry there has been a most startling change in the range of choice open to all but the very poorest groups of many communities. Whilst no one would wish to deny the advantages to be derived from variety and flavour it is equally a mistake to despise the simpler diets of the past, or to regard them as necessarily inferior, at any rate from the nutritional standpoint.

In his Cantor lectures for 1938 Drummond has traced many of the interesting changes that occurred from Mediaeval times onwards in the diet of the English, culminating towards the end of the nineteenth century with such unfortunate developments as the degermination of flour and the introduction of margarine Whilst on the whole the gains exceeded the losses he points out that the best fed members of the population to-day, though getting perhaps twice as much vitamin B_1 as people on a low income level, yet consume less of this vitamin than the parish poor of the eighteenth and nineteeth centuries. The same remark might be applied to this country, except that we must compare our own diets with the Natives of the Reserves, who are often still consuming prodigious quantities of home-ground whole-meal mealie meal, or for that matter whole mealies themselves.

With certain unfortunate and important exceptions, it may be said, however, that the food habits of the Western world have been tending to change in the right direction; on the whole the evidence shows that in addition to the indispensable foods of high energy value they are consuming more milk and dairy products, more fruit and more vegetables than a generation ago. Doubtless many factors are responsible for bringing about these improvements, amongst which the growing interest in the subject of diet, the greater dissemination of reliable information through cookery books and magazines, as well as lectures and demonstrations, play a valuable part.

Special mention must be made of the remarkable efforts of the Health Organisation of the League of Nations to focus opinion

and direct action on the scientific side. The systematic nature of the work sponsored by this organisation and the world wide study that is now taking place as a result is likely greatly to accelerate the rate of change. One cannot but be impressed by the thoroughness and magnitude of the attack which is now being made upon the problems of malnutrition, which, to my mind, is an excellent example of the working of that active principle in man referred to by Dr. Malherbe at our last annual meeting, an active principle which is constantly seeking to control its environment and to which we must look if we wish to achieve progress. A noteworthy feature of the work of the League has been a steady insistence on the view that nutritional problems cannot fruitfully be studied in a narrow setting; rather must they be visualised as a web of relationships involving geography, agriculture, medicine, economics, sociology and kindred subjects. It is in this broader setting that I want to deal with the subject of my address.

Nutrition as a Problem of Physiology.

Whilst it is true to say that from the dietetic standpoint the broad principles of nutrition have now been fairly well established and that we know what is meant by an adequate diet and can express it in terms of its chemical constituents with some degree of accuracy, there is much about the subject of nutrition which still remains uncertain and obscure. This is partly due to a lack of technical knowledge, but arises mainly from the well nigh inscrutable complexities and variability of the living organism; for the human body is indeed of a totally different order of complexity from that of any chemical system that man has ever constructed or worked. Remarkable progress has been made, but owing to considerations of an urgent practical nature a tendency has developed to express this progress with a dogmatism, an over-simplification and precision, which does not seem to me to be warranted, as yet, by the facts. Now we are an association for the advancement of science and I do not need to persuade you that such a state of affairs is bound to prove unsatisfactory in the long run, or that for its true advancement the science of nutrition must needs keep as close as possible to the narrow and less comfortable path of strict scientific accuracy. Hence, instead of recounting the brilliant triumphs of recent years, which in any case will be well known to you, I have deliberately chosen the aspect which seldom seems to receive much attention, namely, the formidable difficulties that confront us when we turn from the qualitative to the quantitative aspects of the subject.

1. *Chemical Composition of Foodstuffs.*—In the first place it is not always sufficiently realised that, as yet, we possess but a very rudimentary knowledge of the chemical composition even of the commonest foods.

Thus the value usually given for protein merely consists of the total nitrogen content multiplied by an arbitrary factor, which has to be varied more or less empirically for different foods; little attention has been paid to the amount of nitrogen that may be present in other forms. The "protein" content of the common mushroom is a well known example of the errors that can arise in this way. Moreover, the nutritive value of a given protein depends upon the kind and amount of the particular amino-acids which it contains; yet so difficult are the methods of analysis that it is, as yet, impossible to arrive at anything but the roughest approximation of say, the tryptophane content of a given diet.

Figures for fat merely denote the amount of the foodstuff that happened to dissolve in ether; usually this includes numerous other substances, some probably of great importance, as well as the glycerides of the three main fatty acids.

Carbohydrate is very often obtained by that delightful procedure known as the method of difference, which ensures that the analysis shall add up to one hundred, but is quite unable to differentiate between mono- and di-saccharides, pectins, pentosans, starches, or even indigestible fibrous material, though nowadays it is true that fibre is usually determined separately.

Finally, the calorific value of the foodstuff is determined by multiplying the figures arrived at as above by factors that include several awkward assumptions and adding the products obtained; yet many an industrious nutritionist will triumphantly record the total calorific value of a complex diet to a decimal of a calorie!

Difficulties regarding the estimation of the mineral salts are largely technical in nature and are being overcome, but of recent years it has been found that some substances such as phosphorus and iron vary greatly in their availability, according to the form in which they occur, or to the interfering effect of other substances in the diet. Iodine, copper, fluorine and manganese have all been shown to be of significance, but what of the many other elements whose presence in our common foodstuffs has been established by spectroscopic analysis?

2. *Variation in Composition of a given Foodstuff.*—A second difficulty depends on the fact that a given foodstuff may vary considerably in its chemical composition because of differences in the soil, the rate of growth, the variety, the various parts of the plant and so on. Average values reduce the magnitude of this source of error in the ordinary mixed diet, but where a single food is used in large quantities these differences may be of real significance. We may illustrate this point by reference to whole-ground maize meal (see Table 1), perhaps the most important food in the country.

TABLE I.

TABLE TO ILLUSTRATE THE VARIATION IN COMPOSITION OF DIFFERENT SAMPLES OF A SINGLE FOODSTUFF.

Percentage Composition of 28 Samples of "Straight Run" Mealie Meal obtained from various parts of the Union.*

	Minimum value	Average	Maximum
Moisture (gm.)	10·7	12·1	14·5
Protein (gm.)	7·5	8 6	10·7
Carbohydrate (gm.) ...	68·5	71·5	73·8
Fibre (gm.)	1·4	2·1	3·0
Fat (gm.)	3·4	4·6	5·3
Mineral Salts (mgm.) ...	800	1,100	4,400
Calcium (mgm.)	6	20	52
Phosphorus (mgm.) ...	146	203	274
Iron (mgm.)	1·2	3·8	7·1
Calories per lb.	1,506	1,628	1,736
Calcium per lb. (mgm.) ...	27	90	234

* Data kindly supplied by the Chief of the Division of Chemical Services.

One further example must suffice. In 1932 Cowell was experiencing unexpected difficulties in some calcium balances he was making with rabbits; investigation showed that the outer dark leaves of the cabbage he was using contained as much as 998 mgm. calcium per 100 gm., though the yellowish-white inner leaves only contained about 32 mgm. Very often the food analyses employed in dietetic work are derived from work done in 1906 by Atwater and Bryant; these workers state the ranges they observed and an examination of their tables is illuminating.

Remarkable progress has been made in the last few years with the quantitative estimation of the vitamins in our different foodstuffs, but similar wide variations are met with, whilst technical difficulties must also be taken into greater account. Thus, according to the reported values, the ascorbic acid content of the banana varies from 1 to 15 mgm. per 100 gm. Milk from pasture fed cows may contain as much as 2,000 units of vitamin A per litre, although values as low as 700 have been obtained for stall fed animals. No doubt marked differences would be observed between the milk from cows living on summer and winter pastur-

age in South Africa. The difference in the anti-scorbutic value of different varieties of apple has been established for some time.

Finally, the chemical composition of a food is often greatly influenced by the manner and length of time it has been cooked, or even the time that has elapsed after cooking and before serving. Cooking makes some constituents more available, but others may be leached out or even completely destroyed.

Enough has been said to indicate that the actual composition of a given diet may differ considerably, both qualitatively and quantitatively, from the figures which appear on the chart of the unsuspecting dietician.

3. Much attention is now being given to the working out of detailed diets for general application. Such diets are of two main types, namely, " minimum " diets, in which the aim is to obtain the best value for the least cost and " optimum " diets, which may be defined as containing minimum requirements for health plus an additional allowance for unforeseen eventualities. The latter constitutes the margin of safety and the allowance made can naturally be little more than guesswork, even supposing our minimum requirements were capable of exact definition. Thus, owing to its expense the minimum requirement for protein has been the subject of much discussion and experiment. Very careful consideration of the evidence has led to a figure of 42 gm. of protein per day being accepted as an average value for the requirement of a 70 kilo. man. However, it is but an average, for there is good evidence that nitrogen equilibrium *can* be maintained on only half this amount, whilst the Esquimaux are reported to thrive on over six times as much. Whilst common sense tells us that some margin of safety above minimum requirements is desirable it is not possible to state with any degree of precision just what this margin should be moreover, there are proteins *and* proteins. It is only recently that much headway has been made with the quantitative aspects of vitamin chemistry, but already tentative minimum and optimum requirements have been suggested, which should serve as interesting guides for nutritional work. The considerations on which these provisional estimates have been based are fully discussed in a series of papers appearing in the Journal of the American Medical Association for 1938. Judging by the standard proposed for vitamin C by some authorities the majority of male Natives in South Africa should be suffering from advanced scurvy!

Man is the only animal species who is able to live *and thrive* both at the Poles and the Equator; do we not sometimes tend to underestimate the fundamental nature of this power to adapt and to endure?

The simplest diet of which I am aware is that said to be used by the Buganda, a people living in Uganda, who manage to subsist almost entirely on a species of banana, which they cook whilst still unripe. For sheer tenacity of living under unfavourable

circumstances it would be hard to rival the record of Philippe Thibaudot, who, in the Middle Ages lived in France as a recluse in a tiny cell; though scarcely able to move and entirely dependent upon the generosity of the passer-by she is stated to have lived, or shall we say existed, from her eighteenth to her ninety-ninth year!

Human experience has long since demonstrated that with the exception of water, no single food is indispensable; nutritional science is gradually teaching us why this is so and is liberating us from the tyranny of diets expressed in terms of this or that particular food and is establishing our fundamental requirements in terms of relatively simple chemical substances such as glucose, tryptophane, calcium and ascorbic acid. Such requirements can be assembled in countless ways, hence the diversity of foods with the same nutrition. However, it will not be until this process has advanced still further that we shall be in the position to study the effects produced by varying one constituent at a time; until then estimates of minimum or optimum requirements of this or that must be regarded somewhat in the light of inspired guesses. For the time being these mean values, often based on balance experiments of but short duration are all we have to go on; they are indispensable guides for gauging the quality of a given diet, but they must be recognised for what they are, namely, tentative working standards, rather than rigid minima, below which ill-health must be assumed to be inevitable.

4 Whilst we are on comparatively solid ground when dealing with the average requirements of large groups of individuals surprising discrepancies appear when we are dealing with the individual himself.

No other aspect of nutrition is so amenable to precise measurement or has been so carefuly studied as our intake and expenditure of energy. Yet in 1936, in some admirable studies, Widdowson clearly demonstrated that whilst the " average man," as has been repeatedly shown, consumes about 3,000 calories per day, " the individual variation is enormous, even amongst those whose lives are of similar activity." She quotes, for example, the case of two male subjects, both of the same age and build and of very similar occupation, the one being slightly overweight on a daily intake of 1,772 calories, whilst the other was not overweight though obtaining 4,955 calories daily from his food. Any frank student of nutrition could produce similar anomalies from amongst his cases. Quite apart from possible racial differences, about which next to nothing is known, it is becoming clear that individuals must, at any rate, be classified into several distinct nutritional types. One such type may thrive on a diet which would prove quite unsuitable to another; indeed, in the extreme case one man's meat is always literally another man's poison. Whilst much can be explained or at any rate explained away, by considerations involving such constitutional realities as poor

absorption, allergy or variation in endocrine adjustment, it is probably best for the present to admit that much remains to be learnt about the nutritional aspects of the chemistry of the individual.

5. *Assessment of Nutrition.*—There will be those who may regard the foregoing somewhat academic considerations with impatience, for surely the proof of the pudding is in the eating, the simple test of a diet is the state of nutrition to which it gives rise?

Unfortunately, it is just here that we encounter our most serious difficulties, for not only is the state of nutrition of an individual the resultant of many other factors apart from, or in addition to the diet he consumes, but it is also a most elusive quantity to assess with any degree of precision.

It seems to us most unfortunate and certainly most unscientific that such terms as nutrition, undernourishment, malnourishmentment, malnutrition, are being used so loosely, without any generally recognised agreement as to the meaning which is to be attached to them and more especially with the implication that nutrition and food are equivalent terms. We owe a debt to Professor Cathcart who persistently points out the dangers to which such confusion can lead. He would have us reserve the term " nutrition " for a wide conception of the state of well-being which characterises the individual who is both physically and psychically sound; in other words nutrition implies function rather than food; similarly malnutrition means disorder of function rather than a condition of the body.

Even if we admit, as indeed we must, that an inadequate or unsuitable supply of food is often, or perhaps generally the *most important* cause of malnutrition, it is seldom the *only* cause. Thus in the case of children other common factors which may exert a decisive influence include faulty food habits, physical defects including inability properly to assimilate the food (either resulting from some constitutional disability, or the existence of some diseased condition such as parasitic infection), neglect of general hygiene, such as sufficiency of fresh air or exercise, insufficient sleep, producing undue fatigue, worry over school work, unhappiness in the home, etc., etc. That such factors are difficult or impossible to detect by any process of rapid examination is obvious enough. The present tendency to equate satisfactory and unsatisfactory nutrition with the consumption of adequate or inadequate diets—the conception of " effortless health through diet " as it has been termed—is therefore inaccurate and misleading. Cathcart is surely right here when he warns us that this is the way to undermine the faith of the " man in the street "—the man we all wish to help—in science and the scientific worker.

Secondly, whilst there is no need to point out to such an audience as this the desirability of being able to recognise and

assess nutritional states, the difficulty of accomplishing this with any degree of accuracy may not be so generally appreciated. To begin with, we have as yet no true standards of normality, with which to make our comparisons; thus our present standards of normality for growth should be considered as average under imperfect nutritional conditions, rather than as optimum. If we depend on clinical assessment we find that well marked personal variations occur when different observers are dealing with the same children at the same time, or for that matter, even when the same examiner deals with the same children at different times. Hence many attempts have been made to substitute or support clinical assessment by various kinds of objective measurements. These measurements and the indices derived from them all have their particular advocates, but the general opinion is that they still leave much to be desired. In any case " as there is no means of knowing when such an index performs satisfactorily, except by comparing it with clinical assessment, which is itself unsatisfactory, the performance of these indices cannot be assessed with any certainty." Fortunately, when applied to large groups of individuals these difficulties lose much of their significance, but the trouble again appears when we wish to compare the results obtained under one set of conditions, with those under another. Until recently nutrition has been usually regarded as a static condition; a newer and more promising outlook is developing, as a result of tests designed to measure function. We then learn that when required to set his chemical machinery in motion the sleek and well-upholstered individual who scores heavily by somatometric methods may make but a poor show as compared with his thinner but " wiry " competitor.

Another recent development has been the elaboration of various tests to determine the state of the individual's reserves of various vitamins. These tests are new and are still on trial, but the early promise that they offered scarcely seems to be justified by more extended experience.

6. Finally, a plea must be made for the psychological aspect. Food is not merely nourishment, but one of the pleasures of life; indeed, to some unfortunates, one of its few pleasures. Moreover, when all is said and done food is only of value after it has been digested and adsorbed. Not only are more and more disorders of nutrition being traced to disorders at this stage of metabolism, but the whole process is closely dependent upon subtle factors of a psychological nature. " When a man opens the door in the evening and says ' something here smells good,' the process of good nutrition has begun."

In the preceding paragraphs I have tried to emphasise some of the main difficulties that arise when an attempt is made to analyse and measure the mysterious processes whereby we are nourished. You will recollect why I chose this somewhat negative aspect for consideration. But, although it is true that we

have so much to learn I would like to conclude this section by stressing once more the really astonishing progress of recent years and the startling practical results that are already being obtained. Moreover, we are only at the beginning of these developments. May we not confidently expect that ever more satisfactory improvements in the general standard of health will be forthcoming when this newer knowledge of nutrition has been systematically applied over several generations?

Nutrition and Agriculture.

During the last few years there has been an almost sudden awakening to the close interdependence that exists between the problems of nutrition and those of agriculture. Hence it comes about that the student of nutrition finds himself compelled to taken an interest in such matters as soil fertility, pasture research and agricultural policy, which at one time would have been regarded as entirely outside the scope of his subject.

Whilst the necessity of conserving the natural resources on which the food supplies of the present and the distant future must depend, is obviously of importance to any country, it has an urgency in this country which it is hard to refer to in measured terms; for it appears that the whole basis of our food supplies rests on a precarious foundation, which threatens rapidly to deteriorate. Fortunately, at a gathering such as this, there is no need to do more than remind you of these issues; indeed I need only to quote very briefly from the symposium held at the last gathering of the Association. Discussing the need for the conservation of our natural resources, Dr. A. L. du Toit said:—

> "It comes to this, that in South Africa, in contrast to most temperate countries, the soil has to be treated more carefully, that large crop-yields cannot be expected, that much of the pastoral section cannot be grazed so intensively and that in the case of soil deterioration or erosion timely remedial measures must be taken and continued with more solicitude and application and over longer periods. Failing such, irreparable damage can only result."

And Professor J. Phillips writes:—

> "We do not yet realise, as a nation, that our country's most precious material possessions, its vegetation, its soils, its water, are being taken from us by three national foes—Deterioration, Ignorance and Procrastination."

Should there be any tendency to ignore the warnings of our own prophets we may note the even sterner warnings of such impartial overseas authorities as Jacks and Whyte, who remark in their recent book "The Rape of the Earth":—

> "In no other country have the disastrous consequences of erosion followed so quickly after its commencement . . .

A national catastrophe due to soil erosion is perhaps more imminent in the Union of South Africa than in any other country. The present standard of fertility will be inadequate to support a white civilization when the mines are exhausted''

As scientists, accustomed to ponder over cause and effect, it may be easy enough for us to grasp the significance of these prophecies and to admire the efforts that are being made to grapple with them. But we must do more than this; we must all do what we can to bring the issues home to the general public and to press for more adequate support and encouragement in the work of investigation and action, upon the results of which the whole future health and happiness of this country is evidently so dependent.

Moreover these problems are all closely linked together; thus, as Professor Phillips pointed out in the same paper, our problems of soil conservation, beef production, nutrition of Europeans and Natives, are closely interrelated with the problem of the wisest utilisation of our main crop—maize. " Too much maize," he says, " leaves the farm, too much leaves the Union, too little is the return obtained, for the soil, for stock, for the farmer, for the community at large."

Another matter which raises points of considerable interest is the difference in nutritional situation to be found in different parts of the Union; owing to differences of geography, soil and climate, it happens that there are noticeable, often very well marked differences in the nature and variety of the foods available in such areas. In some districts, for example, milk is easily produced and is both abundant and cheap; elsewhere, either for parts of the year, or even on occasion for longer periods, the supplies may be inadequate or totally lacking. Similarly with vegetables and fruit; even a few miles outside the Witwatersrand area it is often most difficult to obtain vegetables, other than those locally grown. Owing to the low density of population and the great distances, such inequalities of supply cannot always be satisfactorily overcome by transport, hence local differences in the nutritional situation assume an importance unknown in smaller and more densely populated countries. These practical difficulties require careful study, for it will readily be seen that a cheap and satisfactory diet in one district may be unobtainable or most expensive in another.

This is but one small illustration of the need for investigating the nutritional problems and food resources of the Union and its ten million inhabitants. Quite recently Dr. Haylett has provided us with a most useful preliminary estimate of the situation and it is most satisfactory to learn that at the present time the Department of Agriculture is undertaking a detailed agro-economic survey. From the scanty data already obtainable Haylett endeavours to compare the food available for consumption with

that which may be assumed to be required. Amongst other conclusions he remarks that "farming production in the Union is probably lagging behind the normal nutritional requirements of its present population" and that this shortage is particularly acute in respect of animal products. When these requirements are more clearly focussed it may be possible to re-shape agricultural policy in such a way as both to improve our food supplies and safeguard the fertility of the soil.

The limited nature of the local market is usually stated to be the chief factor that restricts production, though even with the cheapest foodstuffs there sometimes appears to be the most glaring discrepancy between the available supplies and reasonable requirements. Thus, next to the mealie and the potato, one of the cheapest, most nutritious, but also most neglected foods that we produce is the humble ground nut. This amazing little nut is almost pure food; it contains about 25 per cent. protein, about the same amount of carbohydrate and nearly 40 per cent. of fat, yielding nearly 2,500 calories to the pound. Moreover, "it fits well into the farming systems of the drier, warmer areas of the Northern Transvaal." (Union Yearbook). The industry is prepared to supply nuts of fair average quality at 2d. per pound in bulk at Johannesburg. Present production averages about eighteen million pounds of shelled nuts, yet the edible market only utilises about five million pounds. Taking the European plus the Urban Native population for 1938 as approximately four million this amounts to an average daily consumption of about two nuts per head! A greater consumption of ground nuts would be a most valuable addition to the diet of the rural Natives; well liked by children there are many ways of using this excellent foodstuff which has real possibilities where cost is the prime factor.

NUTRITION AND ECONOMICS.

Few will dissent from the view that the most important single cause of malnutrition is poverty. In the United Kingdom Sir John Orr has shown that from four to five million people can only afford to spend four shillings per head per week on food, whilst another six million can only afford six shillings; yet it has been found difficult to devise a reasonably attractive diet of adequate nutritional value in that country for less than seven shillings. According to the Registrar General the corrected general mortality rate in a depressed area, such as Merthyr Tydfil, exceeds that of a well-to-do district such as Epsom and Ewell by 166 per cent.; in other words, in England much ill health can be avoided if you can afford to avoid it.

A recent number of "Race Relations" contains a most comprehensive survey of the nutritional problems that confront the various races in South Africa and the part played by low purchasing power is very clearly demonstrated. Yet, as we all know, whilst consumers complain of low wages and high prices,

producers in South Africa, as in other countries, are equally loud in their complaint of inadequate returns for their labours; even middlemen, the usual scapegoats, are often able to prove the smallness of their margins of profit. The Government, in desperation, yields to pressure from this sectional interest or that. Unfortunately, in this country the situation is further complicated as far as the producers are concerned by the extreme uncertainty of the rainfall, as well as the prohibitive costs of distribution to a small and very scattered home market. Although the fundamental nature of the relationship between economics and nutrition is self-evident, it is impossible to do more than select a few aspects of this highly complex matter for very brief consideration.

1. Is plenty *possible?* In the first place, as scientists, it is well to ask ourselves what are the technical possibilities of producing the food required in the world to-day; and here it is worth remembering that man's daily requirements are really small and fairly constant. In India there is a saying that for every three mouths there are only two rice bowls and it is not so long ago that food supplies were very generally limited by the technical difficulties associated with production. Moreover, the growing of food was formerly undertaken in much the same way as it is to-day in the Native Reserves, i.e., almost entirely to meet the needs of the family, or at least of the small local community. The persistent application of science to the problems of agriculture and animal husbandry as well as the concentration of populations into town has gradually revolutionised the situation, both by increasing production enormously and by divorcing it from known requirements. Nevertheless, the fertility of the soil can now be adjusted and to a considerable extent indefinitely safeguarded, improved types of plants and animals have increased yields and resistance to disease, means of controlling pests have become more and more efficient, machinery has displaced the slow cumbersome methods of the past and many crops or agricultural products can now be stored, in some cases for almost unlimited periods. Moreover, the promise of future developments is no less revolutionary. There are some who go as far as to say that if the available good agricultural land of the world was worked by the best modern methods they could, even now, provide a food supply somewhere between two and twenty times the amount required for the optimal standard of the present world's population. Others, I gather, are not quite so optimistic, but few would not agree that even a minimal application of existing scientific knowledge would lead to a most dramatic increase in the production of food; surely the present problems of "over-production" are to some extent proof of this contention. May we not therefore say that the scientific problem of the production of the food we require has now been solved and that the first main step towards good nutrition has therefore been taken?

And yet although this era or plenty has now become *possible*, the obstacles to its actual achievement are as formidable as ever; but they are now economic and political rather than technical in character; in other words, we have entered on a new phase of the problem. Unable to believe in our new found powers we have merely become embarassed by them. We now read of the "grave problem" of a gigantic world over-production of wheat; "surplus" milk is thrown into the canals of Holland, the American farmer is being paid not to raise hogs, the Brazilian planter burns his coffee, the English farmer is fined for producing too many pigs or potatoes and here in South Africa we are puzzling over what to do with record crops of mealies and oranges that no one is supposed to want.

Personally I do not doubt but that this "splendid problem of plenty" will be solved, as the problem of production has been solved; but we cannot go backwards, it will never be solved by doing away with the plenty. Some obvious first steps were clearly expressed by Mr. Bruce in 1935, when, in words that have since become famous he stressed:

> "the necessity for marrying agriculture and public health *in the interests of the latter;* of increasing the consumption of protective foods *as a remedy for malnutrition and the agricultural crisis* and of changing the incidence of State protective subsidies so that they should serve to *increase consumption rather than restrict production.*"
>
> (Italics ours).

2. *Action Based on Requirements.*—As Bernal has pointed out in his stimulating book "The Social Function of Science," once it has become possible to establish scientifically both minimal and optimal standards of nutrition, far more political and economic action in favour of realising them can be taken than when equally real hunger was expressed in unassessable terms. Once a need can be defined in more or less quantitative terms its satisfaction becomes a definite technical and economic problem. If organised society determines that the need shall be satisfied and is prepared to meet the cost it becomes a purely economic one.

3. *Producers versus Consumers.*—How weak is the link between the needs of the producer and consumer has been stated very plainly, though perhaps a little badlly, by our Secretary for Agriculture, who, in his last report, remarks that agricultural products cannot be sold at prices which are inadequate even to cover production costs *merely* to ensure that all sections of the community are properly fed. But the consumer must eat and some idea of the extent to which he is subsidising the producer, whether efficient or otherwise, is indicated by comparing the prices he is compelled to pay with those at which the same foodstuffs are available outside the Union. (See Table II).

TABLE II.

COMPARISON OF PRICES CHARGED IN UNITED KINGDOM AND SOUTH AFRICA FOR SOME COMMON FOODSTUFFS.

(From Monthly Bulletin Statistics, April, 1939).

	United Kingdom.	South Africa.
Maize per bag	6s. 6d.*	10s. 6d.*
Wheat per bag (200 lb.) ...	7s. 5d.	22s. 0d.
Flour (25 lb.)	4s. 1d.	6s. 5d.
Bread (1 lb)	2·1d	3·5d.
Sugar per lb	2·5d.	3·4d.
Cheese per lb.	10·8d.	1s. 4d.

* Figures given by Mealie Control Board.

The real difference in price is considerably greater than these figures indicate owing to the higher cost of other necessities such as rent and clothing in this country, and there can be no doubt that this policy of subsidising producers by consumers places a very heavy burden upon the resources of the poor. If we are really in earnest about improving our national health standards is it not urgently necessary to find out just what this country is most fitted to produce, using the most efficient methods, and then, if the cost of production still exceeds the purchasing power of the poor, to bridge the gap by means of a subsidy applied at the consumer end by taxing the wealthier members of the community?

4. *Costs of Distribution*—Another outstanding feature of the present situation is the magnitude of the discrepancy between the return to the producer and the retail price. Although some intermediary processes are obviously essential there must be many of us here who find it hard to believe that these processes could not be considerably simplified and cheapened.

5. *Waste.*—Although we may live in a world of potential plenty it is still essential to avoid waste; here are four examples of different types of waste that have come to our notice:—

i. *Undeveloped Resources*, e.g., fish.—Notwithstanding the existence of vast unexploited areas the Union's marine resources are only developed to a very limited extent; admittedly there are many practical difficulties, such as the lack of natural harbours, the use of somewhat primitive methods of fishing and the problems associated with distribution. However, a Fisheries Survey, carried out in 1932-3, reported that there was ample scope for an expansion of the industry. They pointed out that although the per caput consumption of fish was insignificant when compared with that of other countries, an unnecessary proportion

was of imported origin. Such fish as the anchovy and herring occur in our waters in great numbers, but they were not then being utilised for commercial purposes. Judging by the very scanty data available it would appear that in spite of the very practical recommendations formulated by the survey little progress has been made in improving this most unsatisfactory state of affairs; for whilst exports have remained at a stationary level since 1933, imports had nearly doubled by 1937. Fish, either fresh or dried, is a most valuable food and the development of a supply and demand for cheap fish, particularly of the herring type, or small fish to be eaten whole, would be a valuable contribution to the solution of some of our nutritional problems.

The present state of the peanut industry already referred to offers another example of an undeveloped source of good cheap food.

ii. Wasteful *use* of Food.—Elsewhere we have drawn attention to the wholesale waste of good protein, mineral salts and water-soluble vitamins that takes place when mealies are converted into highly refined mealie meal and samp. A second example is afforded by the wastage of the same constituents when whole milk is " refined " by conversion into cheese and more especially butter. According to Haylett's figures, if it were possible to ration the whole milk produced in the Union more than a quart per head would be available per day for the European population. As actually consumed, largely in the form of butter, the approximate wastage per head per day is indicated in Table III. Whilst there are many good reasons why such conversion is to some extent inevitable and whilst it is true that a certain amount of the separated milk produced during the process is con-

TABLE III.

DAILY WASTAGE OF VALUABLE CONSTITUENTS OF WHOLE MILK OWING TO THE MANNER IN WHICH IT IS CONSUMED.

	Fat. (gm.)	Protein. (gm.)	Calcium. (gm.)
1. If rationed as whole milk, i.e. 2·2 pints per day	42·5	41·2	1·5
2. As actually consumed, i.e. (a) whole milk, ½ pint; (b) butter, 1 oz.; (c) cheese, ¼ oz.; (d) etc., say whole milk, ⅕ pint	41·1	15·3	0·54
Daily loss	1·4	25·9	0·96
Percentage of original constituent wasted	3·3	62·9	64·0

sumed by human beings, the fact remains that these processes are responsible for a tremendous wastage of most valuable "protective" food. Every effort should be made to reduce this waste by developing the consumption of whole milk as such, or by the encouragement of the production of high class dried milk powder, which preserves almost all the original nutritional value.

iii. Malnutrition is an extravagant luxury.—Reckoned in terms of low vitality, impaired efficiency, actual sickness and consequent hospitalisation the total cost to the nation of poor health due to unsatisfactory diet must be exceedingly heavy; it is a tax which our small white population, with its peculiar problems, simply cannot afford to go on paying. Surely this must be kept more steadily in mind when the cost of preventive measures comes up for consideration, for such expenditure is one of the best investments for the future. Of all such measures none are more likely to produce significant and lasting results than those designed to bring the protective foods within the reach of the low-income and impoverished sections of the community. Hence such steps as the State-aided milk and butter schemes are most encouraging developments; not only do they tackle one of the most urgent aspects of the problem, but the milk scheme, at any rate, also benefits the producer. Because of its safety and ready transportability and for the other reasons mentioned above, it would probably be an even better plan to produce and distribute a really high quality dried milk.

iv. *Taking Care of our Labour Supplies.*—Similarly, it is the utmost folly to disregard the health of the Bantu population and to close our eyes to the well nigh desperate nutritional problems with which they are faced, both in town and country.

Even if other reasons are disregarded there is the reason of self interest. The Native is the keystone of our industrial prosperity and the present acute shortage of Native labour, which is making itself felt both in industry and agriculture, will have served a useful purpose if it forces us to take a little more interest in the biology of the situation. According to the recently issued report of the Farm Native Labour Committee the diet issued to Native farm labourers consists of little else but mealie meal; only about 20 per cent. of farmers in the three northern provinces give meat or milk as a regular issue, though it is true that in many cases an increasingly limited amount of grazing and some other facilities for growing food may also be provided. Such inadequate diets are partially responsible for the notorious inefficiency of much of this labour; no wonder too, that the farm labourer migrates if he can discover more satisfactory employment elsewhere. The report appears to accept the common view that there is an almost inexhaustible supply of healthy male Natives hidden away somewhere in the Reserves. The following figures based on the 1936 census may help to indicate the extent to which the available supplies are already being drawn upon.

TABLE IV.

TABLE TO SHOW THE EXTENT TO WHICH NATIVE MALES FROM THE RESERVES ARE ALREADY EMPLOYED IN THE UNION.

	Cape	Natal and Zululand	Swaziland
Resident males	618,720	741,600	64,679
Absentees at Census date ...	181,025	117,733	9,451
Total male population ...	799,745	860,333	74,130
Absentees as % of total male population	22·5	13·7	12·7
Absentees as % of male population aged 18-44* ...	67·8	41·1	38·1

* These figures are based on information indicating that the number of males between the ages 18 to 44 (i.e., those acceptable for the gold mines), can be taken as about one-third of the total male population.

Using similar methods we have estimated the absentees in the age group 18 to 44 in certain Cape areas to be as follows:—East Griqualand, 78·6 per cent.; Pondoland, 51·8 per cent.; Tembuland, 76·3 per cent.; Transkei, 78·0 per cent.

When examining this table it must be remembered that many of the males recorded as resident were in reality merely at home for a temporary period; others, too, were no doubt unfit for hard physical labour; on the other hand no account has been taken of those who may be at work, but who are older than 44 years.

If the nutritional foundations of life in the Reserves were sound and stable such a heavy drain upon the male population might not be so serious, but it is common knowledge, or should be, that the condition of these areas is not only unsatisfactory but is steadily deteriorating, rapidly in places, more slowly elsewhere. Unless a prompt and most determined effort is made to deal with this situation it is inevitable that whole areas will be turned into desert or semi-desert within a measurable period of years, the population will decline and with it the labour supply. Moreover, as long as the bulk of the family income is derived from industry and not from the land the strongest incentive towards the improved farming methods, which are so urgently needed is absent. Already the startling decline in the supplies of milk is held to be increasing the rate of infant and child mortality, which has always been high. Here we see another of our most valuable national assets being allowed to run to waste.

Nutrition and Education.

Those who have come into close contact with the life of the poor are always the first to emphasise the great importance of ignorance and faulty expenditure of money as prominent contributory factors in the production of malnutrition.

Much can be learnt from a comparison of the diet of the Poor White and the Native. Under normal conditions the rural Native makes use of an extremely simple, monotonous and inexpensive diet, which, as we have shown elsewhere, may yet be fully adequate from a theoretical standpoint; in fact Europeans might well envy the standard of nutrition so often attained. On the other hand the Poor White, with at least similar opportunities, chooses a diet which is quite as monotonous but far less satisfactory, whilst the standard of nutrition attained is notoriously bad. The pages of the medical volume of the Poor White Report teem with evidence to this effect, but my friend Dr. Otto has given me the following example, which recently came to his personal notice. In the Plettenberg Bay district the diet consists practically entirely of bread, sweet potatoes and coffee. A household consisting of father, mother and two sons were found to be using 200 lb. of flour, 100 lb. of sugar and no less than 38 lb. of coffee per month! Often with a little trouble vegetables and fruit could easily be forthcoming. Increasingly, both amongst Europeans and the more sophisticated Natives, the problem turns on what people *will* eat rather than what the diet *could* consist of. Sugar, tea, white bread and tinned foods are preferred, but cost is not the deciding factor. Certainly it is a problem of poverty, but poverty of knowledge and industry rather than *merely* poverty of purchasing power.

Even at somewhat higher levels of income the same factors are at work; thus a recent large scale study in the United States showed that of every ten families spending enough or more on food to purchase adequate diets only from two to four selected diets that could be regarded as good or very good. Moreover, a far greater amount of ill-health and malnutrition occurs amongst the more well-to-do than is generally realised; this can be traced directly to the choice of unsuitable food, or to over-eating.

Custom and tradition play a surprising part in these matters. Thus one reads that in some parts of the Balkans a good many villages observe practically all the orthodox fasts, which may amount to as many as 206 days in the year; in certain regions of Serbia, during the Easter fast, owing to the extreme deprivation of vitamin A, epidemics of night blindness occur amongst the adults and other eye diseases amongst the children. Amongst our own Natives we find women who are not allowed to consume milk during pregnancy and the fact that many Native males regard the eating of green vegetables as effeminate is a fruitful cause of scurvy.

The need for education on these matters calls for brief consideration.

1. Education regarding the conservation of the soil and the *production* of food. The days when farming could be carried on by the rule of thumb methods, if such days ever existed, are now gone by. Especially in this country does good farming mean scientific farming, but it is useless to talk of such things unless farmers are reasonably well educated. Yet the Assistant Chief of the Division of Agricultural Education is reported to have stated recently that of the 18,000 boys who leave school yearly 8,500 enter agricultural occupations; of these no less than 5,000 do not even pass Standard VI.

As far as the Native Reserves are concerned there is a most urgent need for such enlightenment as will arouse the inhabitants to arrest the alarming deterioration of their land and enable them to produce food other than maize for home consumption. Good work has been done, but it is on a totally inadequate scale; however, the stock limitation which has recently been voluntarily agreed to in one or more districts of the Ciskei and Transkei is a most promising response to past educational effort. As for the urban Natives we know of one instance where a large farm is to be set aside for the growing of vegetables and fruit, which are then to be sold locally at cost price; this is to be combined with a scheme for the training of Native lads in gardening.

2. Education regarding the *consumption* of food. There are many obvious ways by which the public can be educated to change their habits regarding the choice and utilisation of food. Thus, the influence of children in bringing about a change in the diet of the home appears to be considerable. Such education should not however be confined to the girls, for the wife cannot be expected to make much headway if the husband does not understand or approve of the changes which are being made. Moreover, there is no reason for restricting such information to the poorer schools, for, as already mentioned, the undesirable effects of malnutrition due to faulty selection of food and to overeating are met with in richer as well as in poorer homes.

There is also a clear case for the education of teachers, administrators and, above all, medical students in the bearing of these matters on their various duties.

With regard to the nature of this education I would like to suggest that there may be a tendency to go overmuch into detail; would it not be better, for most purposes, to make quite sure that the simple truths of the matter were well grasped and well applied? Surely there is no necessity for burdening the mind with details about amino-acids, vitamin nomenclature and units, mineral salts and so on. Rather should we talk in terms of natural foods and the products obtainable form them, of milk, butter and cheese, potatoes, carrots, oranges and other good foods

within the radius of experience and knowledge of the average person. The time thus saved could be utilised to deal with the many other causes of malnutrition for what we want is "balanced habits as well as balanced diets."

Then there is the opportunity of education by example. State and other organisations must see to it that their own institutions carry out the simple principles which they would wish more generally adopted; in this way the right habits will be formed and the taste for good food, suitably prepared, will be encouraged.

Those of us who profess to be students of nutrition need particularly to continue our education and to avoid getting into ruts; a practical difficulty here is to arrange experiments upon human beings; but nowadays, many individuals are experimenting upon themselves and their families and there is room for much more co-operation between the laboratory and the vegetarian, the fruitarian, the Hay diet enthusiast and other voluntary martyrs to the science of dietetics.

Above all, we need as a nation to educate *ourselves* and to give ourselves to a well planned and sustained study of the nutritional problems and resources of our country, doing our best to integrate the knowledge we already possess, so that it can be translated into action with the minimum delay; for indeed time is on the side of malnutrition. Much good work has already been done, or is under way. Thus there has been the Soil Survey, the Department of Agriculture is engaged on an ambitious agro-economic survey, the Department of Public Health is actively engaged in studying the extent and the nature of malnutrition, the Division of Chemical Services has investigated the chemical composition of our common foodstuffs, and the various Boards of Control are closely in touch with many aspects of their particular commodities. But such work is apt to be sectional in outlook, more especially the interests of the nation as consumer receive scant attention. We need the formulation of as long term a food policy as may be practicable, in which the requirements of health, agriculture and industry shall be considered in mutual relation.

In conclusion, therefore, I want to enlist your active support for a proposal made by the nutrition conference held recently at Cape Town, namely, that an organisation should be created in this country along the lines of the national nutrition councils suggested by the League in 1936. Such councils have already been set up in no less than twenty-one other countries and it is clear from the reports now coming in that they are doing excellent work. For example, in Australia, where conditions most closely resemble our own, a council was set up in 1936 and has already published no less than six valuable reports. If chosen on a representative basis I believe such a body could do much to synthesise the findings of the departmental inquiries and could help to apply the knowledge so gained in ways best calculated to promote the health and well being of the people of South Africa.

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THE MICROSCOPE IN BIOLOGY

BY

A. Pijper.

Presidential Address to Section C, delivered 4 July, 1939.

Popular wisdom has it that history repeats itself. On the other hand people are wont to say, and it is especially after a period of sudden and great emotional stress that one hears this, that "things can never be the same again." The contradiction embodied in the two popular utterances is of course more superficial than real.

History has certainly repeated itself in so far as this is the second time that this Association holds a meeting in this attractive City. But those of us who were present at that previous meeting, twenty years ago, will readily admit that things are by no means the same again. There have been changes in the City of East London, and as far as we can judge, they are all for the better. As to our Association, the changes that strike me most, are the disappearance, through death and otherwise, of so many members who made that 1919 meeting such a memorable one. I shall not mention names, but I feel the need to state here that I have not forgotten them.

For to me that 1919 meeting here at East London, and of course also the first half of the week which we spent at King Williamstown, has become an outstanding memory. It was the first meeting I ever attended, and it has become one of the most pleasant recollections of my life. I was a complete newcomer to a gathering, largely consisting of people who had made their mark in science, in comparison with which my own contributions seemed too painfully small, and yet I was received and listened to and made to feel one of them in the most natural manner possible. The encouragement thus received on that occasion has lasted for very many years, and the permanent friendly relations which I have since enjoyed with so many of you, have been extremely helpful in my further scientific undertakings. I regard this my recent elevation to president's rank as a further proof of your kind intentions towards me and I wish to assure you that these feelings are entirely reciprocated. May I add that to my mind one of the most important functions of an Association like ours, though it is one that does not meet the eye so readily, is the encouragement and moral support it can give to its younger members?

The Function of a Microscope.

I have undertaken to address you on the subject of the microscope in biology. Let me at once reassure those who

dread that I shall approach my subject through formulas and cryptic expressions such as numerical aperture, Ramsden circle and diffraction image. I promise that I shall make the minimum possible use of such technical terms, and, if you are interested in them, you can always look them up in the Encyclopaedia Britannica. Some slight knowledge of optics, plus an elementary conception of the various light rays and the rules governing their conduct, and a nodding acquaintance with the constituent parts of a microscope will be quite sufficient to follow my argument. I shall also avoid going at all deeply into the history of microscopy, quite contrary to the accepted rules that govern the construction of the traditional presidential address. My own information on the historical side is scanty, I could of course hurriedly have consulted a book on the subject, but I have always been very much impressed by the dictum in Punch that when you copy from one book, it is just plagiarism, and only when you copy from twenty books, it is research, and I simply had not the time for twenty books. However, I feel sure there is room for a good deal of original research into the history of the microscope, if only somebody would undertake it without any national bias. At the present moment it is extremely difficult to say to which worker in particular a certain advance in methods is due. Did for instance Leeuwenhoek know the method we now call dark ground illumination? In his results there are definite indications that he did. He may have used it, but he evidently never introduced it, and there is always that mysterious story of the one microscope he refused to demonstrate to his visitors from the Royal Society of London. A problem of a different kind is the story of ultra-violet microscopy. There is little doubt that Koehler in Germany built the first apparatus for this purpose, but the practical application and the whole development of the method including the type of apparatus used, has been so completely the work of Barnard that the vexed question of priority seems to lose all its meaning.

Man has been supposed to be adequately defined as the tool-making animal. And then I would unhesitatingly describe the microscope as man's noblest, supreme and most far-reaching tool. It would be a fascinating task to unravel the marvellous effects the discovery of the microscope has had on our lives. It would need at least another presidential address to do them justice. Let me, as a pathologist, just bring one aspect to your mind. Would man ever have succeeded in successfully combating so many infectious diseases (and it must be remembered that the majority of human and animal and plant diseases are infectious diseases), if the microscope had not revealed the existence of the small organisms that cause them?

It is a common error of thought that the value of the microscope lies in making things appear bigger. To bring this error home to you I shall have to make a digression. That digression brings me to the discussion of a novel. In perfectly orthodox circles I believe presidential addresses and novels are

regarded as incompatible, they are not supposed to mix well. Perhaps an exception may this time be made, for this exceptional novel. Last year there appeared, written by a Hungarian author, by the name of Harsanyi, a book under the title of "Eppur si muove." The English translation bears the somewhat unfortunate title of "The Stargazer." Those of you who are familiar with Italian will already have guessed that the book is a historical novel dealing with the life of Gallileo. Novel or no novel, it is one of the most fascinating books I have ever come across. It is full of delightful touches, some of them so skilfully placed by the author, surely himself a scientist, that one must be a bit of a scientist to appreciate them to the full. Just listen how Gallileo puts together his first microscope and starts using it. At first he is terribly excited, he cannot leave the thing alone, and everybody he meets must have a peep through it. Very soon however his interest begins to wane, the novelty palls, the instrument is laid on one side and forgotten. The author makes no direct attempt to explain. But have not many of us been through the same process or have we not witnessed it in others? And is not the explanation of the phenomenon at the same time the explanation of the enduring fascination of the microscope to more receptive minds, in more skilful hands? Gallileo in the novel, like most beginners, merely looked at the ordinary things he could pick up from his immediate surroundings, a leaf, a small animal, a piece of cloth. He certainly saw things bigger, but his mind was not prepared for the method and his material was not prepared, and nothing came of it. There is more to a microscope than that it makes things appear bigger. One has to prepare the material according to the particular microscope method used, and one must have a mind that is receptive to what the microscope reveals. Ask any demonstrator of a first year class of students who are introduced to microscopes. My own demonstrator used to say that it was as dark in our souls as it was in our microscopes. The man who uses a telescope brings things nearer to his eye, he cannot manipulate his objects, and he can do very little to his telescope. The microscopist handles minute quantities of material, which he has to prepare himself, and their very minuteness complicates his task. He cuts, he teases, he fixes, he stains, he adds chemicals, he has to master many delicate techniques before he can have anything suitable to look at. Then comes the choice of microscopic method to be applied, and there are so many of them that one can hardly be an expert in all. And then there still remains the final difficulty, and that is the correct reception and interpretation of what one sees, taking into account the distorting effect, not only of the previous manipulations of the material, but also of the rays of light impinging upon the object.

All this is merely one of the reasons why microscopists regard the traditional question as to how many times a microscope does magnify, as completely beside the point. It

is the quality of the picture that matters, not its size, and the quality of the picture depends very largely on the preparation of the material and the application of the most suitable kind of illumination. No microscope working with ordinary light will ever be able to employ a higher useful magnification than about 800 times. To go beyond that merely results in blurring the picture. This automatic limitation of magnification has not proved to be such a drawback as it might appear. When microscopists found they could not go higher, they exerted themselves to do better with the means at their disposal, and they started inventing supplementary methods. The result has been that the microscopist of to-day has so many methods at his disposal that one can really speak of an embarras de richesses. The unfortunate part is that one also needs considerable riches to avail oneself of all of them.

This considerable expense connected with the more involved forms of microscopy is probably one of the reasons why for instance ultra-violet microscopy has not got beyond the laboratories of the British Medical Research Council. I am not losing sight of the fact that the whole apparatus would probably not have existed if it had not been for the genius and perseverance of Barnard, coupled with the technical devotion of Beck. But the original outlay for the higher and more specialized forms of microscopy, of which I shall give you some examples just now, is rather formidable and not within the reach of private individuals or even the smaller official institutions.

Ultra-violet Microscopy.

Microscopy by means of ultra-violet light is a perfectly natural development of microscopy with ordinary light. The real power of a microscope is not expressed in terms of magnification, but in terms of resolution. The resolution depends on the objective alone, for the eyepiece merely serves to magnify the picture to a convenient size, but does not add anything to the resolution. Now by resolution we mean how close together two points in the object under observation can be to be still observed as two points. The distance between two such points is a measure of the power of resolution of the given objective. Now in the simplest possible words this power depends on two factors only. One is what is called the numerical aperture of the objective. It means more or less how close you can bring your front lens of your objective to the object you are looking at and still get a picture. The closer you get the greater the resolution, but glass being what it is, you cannot get closer than a certain distance, and that puts a natural limitation to the factor called numerical aperture. The other factor is the wavelength of light, and the shorter wavelengths give the greater resolution. In simple terms, the amount of detail that one can see, stands in inverse proportion to the wavelength of the light one uses. Visible light stops somewhere at wavelength $0{\cdot}5\mu$. If one had visible light of a wavelength $0{\cdot}25\mu$, one would see twice as much detail. Light

of that short wavelength is called utra-violet light, it is invisible, but it does affect photographic plates. It is not refracted by glass, but it is by quartz. And so, by replacing visible light by ultra-violet light, and glass lenses by quartz lenses, and the eye by a photographic plate, Barnard has succeeded in photographing bodies at least twice smaller than what the human eye can see. It has probably taken him more years to do it than it has taken me minutes to explain it. The difficulties of getting suitable light, and suitable quartz lenses, and then again, and this I want to emphasize, a suitable preparation of the material, were enormous, but the results were well worth it. Barnard has produced photographs of virus bodies that nobody had thought could be made visible to the human eye. Their existence was suspected, but there was no proof whatever, and most people who believed in the socalled particulate nature of virusses, were careful to add that these particles which were the virus were too small ever to be seen. Barnard, by increasing the scope or resolution of his microscope by one hundred per cent., succeeded in making them visible on the photographic plate, and he is considering now, by using ultra-violet light of still shorter wavelengths, to still further increase the power of his microscope.

Infra-red Microscopy.

The obvious counterpart of ultra-violet microscopy, which achieved greater resolution by employing shorter wavelengths of light, is of course infra-red microscopy. The aim of infra-red microscopy is not greater resolution, but greater penetration. To many of you the words infra-red rays will recall memories of photographs of the coast of France, photographed from the coast of England on a foggy day, the particular virtue of infra-red rays being that their long wavelength permits them to find their way, unhampered, round fog particles. It is probably less well known that this ability to ignore small particles has led to the use of infra-red rays in microscopy. For ordinary microscopic work one as a rule prefers to place the thinnest possible slices of material on the stage of the microscope. Thick slices absorb and hold back too much of visible light, and the impression gained by the eye will just be one of general turbidity. The position however becomes quite different if the visible light is replaced by infra-red rays. Now the infra-red rays will not be affected by the numerous small particles causing the general turbidity, but only by the more solid and well-defined and more compact structures present in the preparation. Here again, infra-red rays being invisible, one has to rely on the photographic plate for the picture. The procedure is somewhat as follows: one focuses the preparation by means of ordinary light as best one can, places the infra-red filter between microscope lamp and microscope, puts the special infra-red sensitive photographic plate in position, and experiments with exposures until the photographic plate on development shows definite structures. I found it for instance possible to photograph

bacteria in the depths of agarmedia, in which they were quite invisible by ordinary microscopic methods on account of the turbidity of the agarmedium. The method has already been extensively used for histological purposes and very curious pictures of thick slices of tissues have been obtained. The microphotographs are sometimes difficult of interpretation, but there is no doubt that here is another field of research in microscopy which leads at once into completely uncharted fields.

Dark Ground Microscopy.

There is one special microscopic method that has always had rather a hard time, and is still struggling for recognition. I refer to what is known as dark-ground microscopy. Is is true that Barnard's ultra-violet microscopy in essence also is a dark-ground method, but with ordinary light the dark-ground principle never has quite got into its own. From personal experience I am convinced that a proper application of the dark-ground method with visible light is capable of solving problems that baffle ordinary microscopic methods. In dark ground one has the inestimable advantage of using live material in normal surroundings, avoiding the injurious processes of fixing and staining. For sheer beauty the pictures are unsurpassed, silver white shining micro-organisms can be seen moving against a velvety black background. Especially when the microscope is provided with binocular tubes, and a stereoscopic picture can be produced, the spectacle of a deep dark layer of fluid, in which bright and glittering organisms and cells and particles move restlessly about, is to my mind greatly preferable to even the Victoria Falls on a moonlight night.

Dark ground microscopy is based on a phenomenon with which we are all familiar. A ray of sunshine penetrating through a narrow slit into a darkened room, when looked at sideways, shows up millions of dancing particles of dust, which are much too small to be seen otherwise. Dark ground microscopy means the application of this phenomenon to the microscope. And here we at once encounter the difficulties attached to the method, and the reason why it is not in more general use. The light has to be brought to the preparation on the miscroscope slide in such a way that it passes through the material without being able to enter the objective, in other words, so that the observer looks at it sideways. All the light that the observer may see must be as it were reflected by the particles in the microscope field. For this purpose special substage condensers have been designed which throw the light very obliquely through the preparation. In order to get as much light as possible, the condensers are so designed that oblique rays enter the preparation from all sides, in circular fashion, and they are brought to a very narrow focus. This narrow focus concentrates all the light, and it is only in this focus that the phenomenon of dark ground illumination shows itself. It follows that accurate centration of light source, condenser and microscope lenses

become of supreme importance, apart from the correct adjustment for height of the condenser with its small focus. Here lies the source of the many failures which have made the method unpopular. It requires endless patience and an experienced hand to get the best out of a dark ground microscope, and there hardly is a second best. Slipshod methods mean complete failure. A well-managed dark ground picture, apart from the advantages already mentioned, increases the visibility of details because they show up white against a black background.

THE CONSTRUCTION OF MICROSCOPES AND LAMPS.

I have said that the dark ground method has not found great favour with microscopists on account of its intrinsic difficulties. But here not all the blame should fall on the shoulders of the microscopists. The makers of microscopes are also partly guilty. There are still far too many microscopes put on the market which do not make adequate provision for easy and accurate centration of condensers and objectives. A revolver for carrying objectives is a very half-hearted attempt at centration, and in most microscopes the substage arrangements are treated like proverbial stepchildren. It is probable that mass-production has something to do with this, but microscope builders do seem to belong to the conservative party. Microscopes in common with motor cars are becoming more and more streamlined, but essential improvements lag behind. Let me give some illustrations. A device for accurate centration of objectives and condensers should not be regarded as a luxury. There is nothing more vexing in microscopic work than to "lose your place," and is there any firm that has invented a really satisfactory method to find it again? There are a few objectives on the market now with adjustable iris diaphragms built into them so that one can vary the numerical aperture at will. Is it asking for too much if we want more of them? Talking of convenience, I do not want to go so far as the old professor who had a support for his cigar attached to his microscope stand so that he could look down and smoke in comfort, but, seeing that motor cars have sliding gear changers nowadays, is it impossible to build eyepieces that allow a gradual increase in magnification? Binoculars are still regarded as an "extra," and it is only quite recently that makers of microscopes have discovered that it is more comfortable to look through a microscope at an angle than straight down. Has any designer of microscopes ever enquired from his customers what alterations they would like? The general pattern of microscopes has changed very little from the early days onward, if one looks at pictures in history books. The old and rather futile controversy whether a microscope should have a horseshoe base or find stability on a tripod seems to have been settled. Lenses used to be built empirically, they are carefully calculated beforehand now. Would it not be possible to apply the same sound engineering principle to the stand? Why should a microscope stand consist of one upright pillar, to which a series

of brackets are attached which carry the various parts? Surely a microscope stand needs stability and can that be expected where all its delicate parts are supported at one point only, instead of at three? At the present time the slightest pressure on the stage throws the whole picture out of focus. I am not referring now to the enormously heavy and solid and bulky apparatus that the larger firms have recently put on the markets, and which are far too expensive and perhaps not very useful to the ordinary worker. It is the ordinary microscope stand that we all buy to which I would like to see applied some elementary principles of engineering.

The criticisms expressed must not be taken to mean that I do not appreciate all the good things the designers of microscopes have given us. It is, I suppose, just human nature to accept what is good without comment, and to dwell on things one would like to see altered. One of the good points about modern microscopes is their internationalness. What I mean is that nowadays a high degree of international standardization has been reached. Practically all modern objectives are calculated for a tube length of 160 millimeters, tubes are generally of such uniform width that they will take any eyepiece, and finally, the screwthreads of practically all makes of objectives are similar and will fit any standard microscope. Here most construction engineers have a lot to learn from the firms that build microscopes.

There are still one or two things I would like to say about microscope lamps. Nobody nowadays uses daylight for microscopic purposes. The advantages of artificial light, especially electric appliances, are great. The surprising part is that so little thought is given to the construction of these lamps. Far too many of them allow a good deal of the light to stray into the observer's eye. This narrows his pupils, and makes his retina less sensitive to the fainter light that his eye receives from the microscope. It is not a minor point, and it also illustrates the little thought that is so often bestowed on such matters. A very serious shortcoming, I think, of electricians is that they have not succeeded in producing a lamp that is really suitable for dark ground work. Sunlight is still several times stronger than the best electric lamp that can be used for such purposes. Such a lamp should be easy to handle, and free from danger. It should have a very small area of very high intrinsic brilliancy. Dark ground methods depend on the contrast between brightly lit particles against a black background. The brighter the light, the more detail will become visible, and I have seen things show up clearly when I used sunlight for dark ground microscopy that remain hidden with any other kind of illumination. Sunlight has the disadvantage of not being always available, and it requires a heliostat for observations of any duration. But no lamp so far can compete with it as regards brilliancy and efficiency, and as long as this is the case, and no simple and efficient artificial light source

of similar power is put on the market, so long will the further progress of dark ground microscopy be held up. This is a great pity, for dark ground examination, especially for the examination of objects in their natural liquid surroundings, has advantages that are unsurpassed.

Fluorescence Microscopy.

This problem of suitable microscope lamps brings me to another chapter of advanced microscopy, which is called luminescence or also fluorescence microscopy. Although the first patents were taken out several years ago, it is only quite recently that the method has been taken into practical use. Here too the lack of an adequate light source has held up progress. Fluorescence as everybody knows, means that many substances have the capacity, when irradiated with light of one wavelength, to send out light of a longer wavelength. In practice the most effective way is to use invisible ultra-violet light for the irradiation The fluorescence of the substances under examination then sends out visible light, and the colour of this visible light is often characteristic of the substance irradiated. In order to apply the method to the microscope, a very powerful source of ultra-violet light is needed, and this need has not been quite satisfactorily filled so far, except perhaps in the case of very high priced apparatus Also, the ultra-violet light can only be brought to the object on the microscope stage by means of a quartz condenser, and naturally one has to use quartz microscope slides. The rest of the microscope equipment, which has merely to convey visible light to the eye, can be left as it is.

At first it seems as if the use of such a fluorescence microscope would be limited to the examination of materials that are capable of fluorescence as such, the phenomenon known as auto-fluorescence or primary fluorescence. In this field important observations have been made, and with the increasing number of substances that are found to exhibit characteristic fluorescence, the method is becoming increasingly useful. It has already led to the discovery of new kinds of cells in the animal organism, which could be picked out by their curious fluorescence. Similarly, some vitamins possess a characteristic fluorescence and their origin and development can be traced by means of fluorescence microscopy. It has been found that live carcinomatous cells exhibit a fluorescence which is not met with in other cells. For examinations of large pieces of material it is sometimes more advantageous not to admit the light through a substage condenser, but to send it down from above, following the method which is called vertical illumination, for which particular kinds of condensers called epi-condensers have been constructed by some firms. There is a good deal of spade work yet to be done in this field, the normal fluorescence of normal cells and tissues of both animal and vegetable origin still have

to be worked out, and probably this new method will be found to give its maximum return only when a spectrometer is added to the microscope in order to analyse the exact constitution of the fluorescence colours. However rich the harvest here is going to be, and it must be remembered that especially plant cells are capable of producing a large variety of fluorescence colours, still more is perhaps to be expected from another application of the principle of the method, which is called secondary fluorescence. Observing primary fluorescence has the advantage of dealing with untreated and undamaged cells, for secondary fluorescence the material has to be prepared and treated beforehand, not however with fatal results to the cells in all cases. The preparation of the material consists of treating them with weak solutions of certain dyestuffs. These dyestuffs are capable of fluorescence to a very marked degree. They have moreover very often a selective action, i.e. they have preferences for certain cells, or for certain structures in cells. These dyestuffs are called fluorochromes and there is already a large variety of them. By their judicious application it is possible to induce all kinds of cells or particles or structures, which otherwise would have remained hidden to give proof of their presence by making them show up in bright colours whilst the background remains dark. It is for instance very much easier to spot an isolated tubercle bacillus or leprosy bacillus in a mass of debris by means of fluorescence microscopy than by any other method. There are several virus bodies for which selective fluorochromes have been found, which make them show up in bright colours in the cells containing them. The method has already been used to show that chinin and atebrin, our remedies against malaria, act by directly penetrating the bodies of the parasites and not in any indirect manner. Here good use has been made of the fortunate fact that both these substances, chinin and atebrin, apart from being good remedies, are also fluorochromes. Recent observations go to show that cancer cells contain small bodies which only become visible by the application of a suitable fluorochrom. But it is not only in pathology, with which I am of course more conversant, that secondary fluorescence has proved its worth in microscopy. In physiology, certain fluorochromes have been used to study the penetration, transport and retention of dissolved substances by plant cells, and there is no doubt that further applications will be found. In these matters we are only at the beginning, and there are still foundations to be laid.

The Electron Microscope.

I have specifically been warned that I must not keep you here longer than fifty minutes. This address therefore cannot be a complete review of modern microscopic methods. But my account would be regarded as very incomplete if I did not make mention of the instrument that first became known

to many of us some time ago through the columns of the daily press. It was made to appear as if through the advent of this "super-microscope" also called "electron microscope," we would all have to scrap our ordinary microscopes and take to the new instrument, for which magnifications of a hundred thousand times seemed to be a perfectly easy matter. Such a magnification would enlarge one red blood cell to a disc of a diameter of seven metres, not a very convenient size to handle. Anybody however who has studied the available scientific literature on the subject will admit that his original feeling of incredulous surprise has made way for a feeling of profound admiration for the German workers who have succeeded in making this miracle possible. Electrons, although in this apparatus they are used for microscopy, have of course nothing to do with light. They are extremely small particles, smaller than the hydrogen atom, they carry a negative electric charge, they are produced by electric discharges in evacuated tubes, and they can be made to travel at an enormous speed. They travel in a straight line, as long as they do not bump up against anything, and therefore the electron microscope has to work in a high vacuum. The electrons being electrically charged, a suitably arranged electro-magnet will deflect them from their course. The secret of the electron microscope is that electro-magnets of particular shape take the place of the lenses in the ordinary microscope. A beam of electrons can be brought to a point or focus through the action of suitably placed electro-magnets. An electron microscope has a substage condenser, an objective, and an eyepiece, all worked electro-magnetically, and focusing is done by altering the strength of the electric currents going through the electro magnets. The advantages are obvious. As there are no glass lenses, the question of numerical aperture disappears. For the same reason diffraction rings cease to interfere with the images obtained. Because there is no wavelength to be considered, the limitation inherent in that factor completely falls away. There is definitely no limitation to the magnification of an electron microscope, figures of a million times have been seriously mentioned, and magnifications of thirty thousand times have actually been reached. A drawback is that electrons not being light rays, the resulting picture cannot be seen directly, but must be made visible by catching the electrons on a fluorescent screen, where a picture will be formed, or on a photographic plate which then can be developed in the ordinary way. The pictures of bacteria that have been published show details inside their bodies that are quite beyond the powers of the ordinary microscope. Quite recently photographs have appeared of bacterial flagella which show very convincingly that the electron microscope can record these delicate structures in an unstained condition. In this case magnifications of several thousand times were easily reached and still give excellent photographs.

Although I therefore have great faith in the future of this new method, also in biology (for metallurgical purposes it has been in use for quite a time), I cannot withhold from you the drawbacks of the supermicroscope. Electrons have a deleterious effect on living cells, the preparations have to be exceedingly thin, one cannot use glass slides but has to use dried preparations on a thin collodium film, and with the usual type of supermicroscope these preparations have to be photographed in a vacuum. Recently a new method has been described which at least circumvents this last objection. Instead of imitating an ordinary microscope, an extremely narrow beam or fine pencil of electrons, which is produced again by a suitable arrangement of electro-magnets in a vacuum, is sent through the preparation to be photographed. This fine pencil of electrons leaves the apparatus through a thin collodium window, and travels a very short distance through the air before it reaches the preparation, which therefore can be kept in the ordinary air. The pencil is made to travel along parallel lines through the preparation, and underneath is a photographic plate which travels in harmony with the pencil, but at much greater speed. The pencil thus etches a very much enlarged picture of the structure of the preparation on the photographic plate. Of course the method owes its possibility to the extreme fineness of the pencil of electrons. The super or electron microscope may not be an instrument for daily use yet, but there is no doubt that it holds enormous promises for the future.

Microscopy and Research.

What is known as the field of a microscope is a very small area, at best it extends over a few square millimeters. I have dwelt on the various aspects of this narrow domain for quite a time, and for fear of being branded as a man of a very narrow outlook I shall now ask you to follow me into a wider field. In truth, my chief aim to-day is not so much to enlighten you about various microscopic methods in detail, as to impress upon you that microscopy is a science in its own rights, worthy of being pursued for its own sake. I want to make you look upon a microscope, not just as a tool that comes ready made from the dealer in optical instruments, but as a piece of apparatus that can come alive in the hands of its user, an instrument that is capable of nearly unlimited development, and which can be the object of research by itself. May I say that this aspect of microscopy is rather neglected in South Africa? And that I always have been, and am, and probably shall be the only South African Fellow of the Royal Microscopical Society? On two occasions I have made tentative suggestions to professors of biology that I should be permitted to lecture to their students on the use and perhaps more suitably, the abuses of microscopes, with perfectly negative results. I have a feeling that this indifference towards microscopy as a self contained science, with research objects of its own, is merely

a symptom of that somewhat too practical attitude that pervades most South African scientific work. I know that with this remark I have got on to very thin ice, or as we rather should say in this country, on to caving ground. Perhaps I had better follow the lead of that lady motorist acquaintance of mine, who made a point of always taking all street corners at the highest possible speed, because she had heard that the greatest danger of accidents was at such corners.

It is undoubtedly true that in South Africa we are surrounded by a number of practical problems that cry out for solution. It is only natural that research workers are powerfully attracted by these problems. There is in addition the atmosphere of competition and rivalry which is a feature of modern times, and which again spurs on the scientific worker towards quick returns and speedy solutions Research in agriculture and industry has to be practical in order to keep in step with the large strides that are being made everywhere. Hardly have we set up an institute for wool research or the very existence of wool farmers is threatened by the production of artificial wool. We have barely found methods to combat horse-sickness or the horse is being superseded by mechanical traction. Whilst our grass researchers have not quite settled yet what is the best kind of grass to go in for under various conditions, the soil erosion department lifts up a warning voice and tells us that unless something is done there will be no soil left to plant the grass on. Our natural resources seem to be dwindling or lose their value whilst we are still engaged on studying them and finding ways and means to preserve them. It is then not to be wondered that most of our scientific work is animated by a spirit of haste, by a burning desire to do something practical. Our attention goes out towards practical application, at the end of the work there must be "something to show for it." The professor can no longer just profess his science, he is called upon, every day of his life, to give practical advice, to help in solving practical problems. The microscope is just a practical tool, like the carpenter's hammer.

It is far from me to condemn this attitude. I have the profoundest admiration for my fellow scientific workers who apply their gifts and energies to these grand efforts to benefit the country and its inhabitants, in so many instances with such conspicuous and far-reaching success. But I would like to use this opportunity to put in a word for an aspect of scientific effort that I am afraid is in danger of being crowded out. I cannot help deploring that what is usually called pure, or fundamental, or academic research is not getting the recognition which, to my perhaps somewhat biased mind, it deserves. It may be due to a defect in my intellectual make-up, but it has taken me some time to get used to the idea that the august body called the Research Grant Board comes under the Department of Commerce and Industry. I personally have the

best of reasons not to say anything in criticism of this body, but are we not agreed that if I apply for a grant from that source, my chances of success will be greatly enhanced if my application can be worded so that it appears as if I was aiming at growing bigger and better oranges, or at doing away with some agricultural pest? And would not my chances of a favourable reply be diminished if I stated frankly that I just wanted to do a piece of pure research, just for the sake of research, the famous piece of research that will never be any use to anybody? There is room and opportunity and need for the kind of research that does not directly lead anywhere, especially in biology. And this kind of research should get the same amount of support and encouragement that is now so largely accorded to research in its more practical application. It is the kind of research that cannot be directed, but it should be fostered. I regard it as a sign of the highest culture, same as art, and it needs leisure and security. The mentality that discovers or invents something new is not always the mentality that can think out practical applications. The practical side often simply does not interest such people. I believe it is on record that the man who invented the electro-magnet, the conception which in the mind of somebody else gave rise to the practical application called an electro-motor, refused to go and see that electro-motor work, he simply was not interested. It would be easy to multiply examples of this kind. It might be objected that my contention that pure research should be publicly supported is all very well and good where geniuses are concerned. In order to counter this objection, I may perhaps be permitted to quote an example, si parva licet componere magnis, to quote an example from very much nearer home. At the previous meeting of this Association in this town, in 1919, I had the pleasure of demonstrating a new method I had just invented of measuring the diameter of red blood cells. It found favour with the Association, and I am pleased and grateful to relate that the Research Grant Board, mainly I believe on the recommendation of this Association, gave me liberal financial support for the further development of the method. But however good the new method was, for years it was practically completely ignored, simply because it did not seem to matter from a practical point of view whether a person's blood cells were a shade bigger or smaller than normal. Until somebody discovered that the diameter of red blood cells is an important factor in the diagnosis of certain diseases of the blood. And then suddenly the despised method became extremely popular and several firms started building apparatus for the practical application of the method, which is now in daily use in most medical laboratories. The point I wish to make is that here we have an example of a new method being worked out merely for the fascination of the thing in itself, which however years afterwards meets with genuine appreciation by practical people. And also that a certain amount of practical, i.e.

financial support is often essential for the proper development of an idea. It is regrettable that modern research whether it is practical or academic, has become so dependent on expensive apparatus. You may remember that when Mrs. Einstein was shown over a new observatory and asked what the truly gigantic mirror of the telescope was for, she was told that it was for studying the universe. "Oh," she said, "my husband does that on the back of an old envelope." To most of us the backs of old envelopes would not suffice as facilities for research. A good deal more is needed, and as scientists are notoriously poor, they have a claim to public money.

Now it cannot be denied that a good deal of public money is being spent on research. It is merely against the stress that is so often laid on the need for immediate practical returns that I would like to utter a mild protest. I have just made an effort to present the science of microscopy to you as a science by itself, capable of higher development, and offering wide fields for research. At the same time it is rather a detached science, from which no immediate practical results can be expected. The pure science of microscopy looks at things just to see how they look under various conditions, but not to find out what they could be used for. It tries to make things visible that are hidden from our eyes, but it is not very interested in their purpose. It rejoices more in the invention of a new method, than in the discovery of new facts, although it is pleasantly aware of it that a new method invariably leads to the discovery of new facts. It does not mind being useful to the practical worker, but it does not set out to be. It is essentially what is called long term research It is this aspect of microscopy that I have tried to bring to your attention. Many of you use microscopes but few of you are microscopists. The fact that so many of you use microscopes should make you pause and consider whether you really get the best possible out of microscopy. And whether some more time and energy might not be devoted to microscopy as such, and some facilities should not be given to those who possess an aptitude for scientific work of this kind? Perhaps a beginning towards a better appreciation could be made by instituting microscopy as a subject to be specifically taught to the young biologist. The present system under which they just pick it up as they go on is rather haphazard and cannot lead to a proper understanding of its possibilities.

Ladies and gentlemen. in looking back on this presidential address I feel that you had probably expected me to say less about microscopical methods and their scientific status and more about actual observations through the microscope. May I remind you that an address on microscopy must necessarily be written during the times when the microscopist sits back, and relaxes, and does not look through, but at, and perhaps even a little beyond, his microscope.

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'N EEU VAN PALAEONTOLOGIESE ONDERSOEK IN DIE KAROO

DEUR

L. D. BOONSTRA,

Suid-Afrikaanse Museum, Kaapstad.

Voorsittersrede vir Seksie D, uitgespreek 6 Julie, 1939

Ek maak geen verskoning vir die keuse van my onderwerp nie. Die palaeontologiese wetenskap word in Suid-Afrika so stiefmoederlik behandel dat dit die plig van iedere palaeontoloog is om die aandag op sy vak te vestig. Dit is haas ongelooflik dat die palaeontologie in Suid-Afrika so min aandag geniet. Veral daar ons Karoo tot onlangs, so te sê, die enigste bron was waar ons kon put ter vermeerdering van ons kennis van die soogdieragtige reptiele van die Perm en Trias. Is u daarvan bewus dat ons met ons oormaat van vier Universiteite en vyf Universiteitskolleges, ieder met 'n afdeling vir aardkunde en dierkunde, geen enkele docent besit wat hom aan die studie van ons Karoofossiele wy nie! Hierdie studie wat hoofsaaklik morphologies en phylogeneties van aard is en wat 'n mens sou verwag juis groot aantrekking vir die akademikus sou hê. Daar is net een verblydende teken nl. dat daar darem een universitêre inrigting—die Universiteit van Stellenbosch—is, wat 'n klein versameling Karooreptiele in bewaring het. Was dit nie vir die optrede van 'n paar van ons Museums nie sou ons amptelik die ondersoek van ons belangrike Karooafsettings totaal veronagsaam het. Die optrede van die drie betrokke Museums is des te meer aanprysenswaardig omdat hierdie inrigtings hul nie soseer toespits op morphologiese ondersoek nie, maar die taksonomies-faunisties as hul arbeidsveld beskou.

Ten tweede maak ek geen verskoning vir die keuse van my onderwerp nie, omdat die toeval dit so beskik het dat 'n palaeontoloog die voorreg het om u toe te spreek op 'n tydstip één honderd en één jaar na die eerste ontdekking van 'n werweldierfossiel in die Karoorotse. Alhoewel die palaeontologie so 'n onbelangrike bestaan voer temidde van al ons ander wetenskappe, kan ons so 'n gebeurtenise egter nie in volslae stilte laat verbygaan nie. Ek lewer dus hierdie beskeie rede—waarskynlik die enigste bydrae—ter viering van die *eeufees* van die palaeontologie in Suid-Afrika.

Dit is treffend dat die ontdekking van die eerste verweldierfossiele van die Karoorotse gedaan is deur 'n persoon wat geen akademiese opleiding geniet het nie. Andrew Geddes Bain was 'n padmaker. Op veertigjarige leeftyd, toe hy naby Grahamstad gewerk het, kry hy 'n eksemplaar van Lyell se „ Principles of

Geology" in die hande en toe kort daarop die meer populêre werke van Buckland en Mantell, wat sy belangstelling in die aardkunde gaande maak. Bain vertel van die begin van sy versamelaarsloopbaan as volg: ,, I was now set up. My zeal knew no bounds, and I literally left no stone unturned in search of fossils or minerals . . . . yet, with all my hammerings, I had not yet found a single fossil. Notwithstanding my bad luck, I was determined to be a geologist". Sy volharding is egter beloon en in 1838 ontdek hy sy eerste klompie fossiele. Die ontdekking van een eksemplaar beskryf hy in sy eie woorde: ,, I was encamped on the Blinkwater . . . . constructing the road through the forest up the Winterberg. In one of my wanderings up the mountain, I saw on the edge of a small krantz some bones protruding which, from their magnitude, might be the skeleton of some huge monster . . . . . I succeeded in extracting . . . . the lower part of the pelvis, a fragment of bony cuirass, the head armed with sixty teeth, and other bones of a large reptile". Hierdie eksemplaar is later beskrywe onder die naam, *Pareiasaurus serridens.*

Bain se versameling het binnekort so aangegroei dat hy 'n kamer vir hul huisvesting in Grahamstad moes huur. 'n Jaar of wat later het hy die hele versameling aangebied as kern vir 'n Museum te Grahamstad. Tot ons skande is die aanbod van die hand gewys en het Bain sy versameling na die Geologiese Vereniging te Londen gestuur. Voor dit verpak is het Bain 'n tentoonstelling van sy skatte gehou. Dit is hier waar die belangstelling van Dr. Atherstone gewek is. Later is Dr. Rubidge, Sir George Grey en Alfred Brown ook, hoofsaaklik deur Bain se entoesiasme, aangesteek. Weens die gebrek aan ondersteuning wat Bain in Grahamstad ondervind het en, in teenstelling daarmee, die aanmoediging wat van die Geologiese Vereniging van Londen en Sir Richard Owen gekom het, is gedurende hierdie tydperk die meeste eksemplare die land uitgestuur. Maar 'n paar eksemplare het tog gedurende hierdie periode van entoesiasme in Suid-Afrikaanse Museums beland—,, presumably those not deemed worthy of export ", soos Haughton dit stel.

Al Bain se fossiele is deur Sir Richard Owen, die vermaarde osteoloog, in 'n reeks referate vanaf 1845 tot 1887 beskrywe en het groot belangstelling in wetenskaplike kringe verwek. Een van die gevolge was dat Prof. Seeley in 1889 na Suid-Afrika gekom het om as opgeleide vakman ter plaatse ondersoek in te stel. By sy aankoms aan die Suid-Afrikaanse Museum en later by die Albany Museum het Seeley eksemplare in hierdie inrigtings gevind wat die moeite van ondersoek beloon het. Wat Seeley se versameltog in die Karoo so vrugbaar gemaak het is die feit dat hy Tom Bain en Dr. Atherstone as gidse gehad het en by Burghersdorp Dr. Kannemeyer en by Aliwal-Noord Alfred Brown as versamelaars aangetref het. Die eksemplare wat Seeley terug na Londen geneem het, gerugsteun deur sy beskrywings in 'n reeks referate vanaf 1878 tot 1908, het die fossielhoudende Karoorotse wêreldberoemd gemaak. Nie net in wetenskaplike kringe

nie, maar ook by leke, het die opstelling van 'n byna volledige Pareiasauriëgeraamte in die Britse Museum die volksverbeelding aangegryp. As gevolg van die oorsese belangstelling het die Suid-Afrikaanse Museums met graagte eksemplare gehuisves maar, weens die gebrek aan 'n opgeleide personeel, het hier te lande nog geen wetenskaplike navorsing plaasgevind nie.

In 1895 het die Cape Geological Commission ontstaan en die geoloë daaraan verbonde het hul vondse van fossiele aan die Suid-Afrikaanse Museum vir bewaring toevertrou. Ongelukkig was daar selfs op daardie tydstip geen opgeleide osteoloog aan die inrigting verbonde nie.

In 1897 het Dr. Broom, 'n opgeleide werweldieranatoom, hom in Suid-Afrika gevestig en met sy koms breek die tydperk aan dat die meerderheid van die Karoofossiele hier te lande ondersoek word.

Sodat daar tot 1911—toe Prof. Watson vanuit Londen 'n versameltog onderneem het—omtrent geen Karoofossiel vir ondersoek die land uitgestuur is nie.

Kort voor Watson se aankoms is Mnr. Walker (1908) en sy opvolger Dr. Haughton (1911) aan die Suid-Afrikaanse Museum en Dr. van Hoepen aan die Transvaal Museum (1910) aangestel en beskik ons Museums toe vir die eerste keer oor die voltydse dienste van geoloë wat in die Karoofauna belangstel. Aangespoor deur die vakmanne het die ou lekeversamelaars Brown, Kannemeyer, Higgins en Putterill met hernuwde ywer versamel en het daar ook nuwe amateurs ontstaan o.a. Whaits en van der Byl.

Tot op hierdie tydstip was die ontdekte Karoofossiele bewaar in die Britse Museum en die verskeie Suid-Afrikaanse Museums met 'n paar eksemplare in Parys en Weenen. In 1913 egter is daar 'n versameling aan die Amerikaanse Museum verkoop sodat ons bronnemateriaal oor drie wêrelddele versprei is, en dit nieteenstaande die feit dat daaral in 1905 as volg geskrywe is nie: ,, ... it is very gratifying to be able to report on the interest which is taken in the collections by many who seem anxious to make the South African collection of fossil reptiles worthy of the country. In the past most of the valuable South African specimens were sent to London, and few ever returned; but within recent years a very healthy patriotism has sprung up and become surprisingly general. As a result our South African collections is rapidly becoming a national institution, and it is fully expected that soon it will no longer be necessary for the South African student of palaeontology to regard the British Museum as his Mecca, but rather will it be necessary for European and American students to make pilgrimage to the Cape.''

'n Paar jaar na die wêreldoorlog het buitelanders, onder die invloed van die referate van Watson, Broom en Haughton, weer aandag aan die Karoofauna geskenk. Vanaf 1923 het die Duitse palaeontoloë von Huene, Janensch, Abel, Reck en Schröder 'n reeks navorsings- en versameltogte in Suid-Afrika onderneem en

het versamelaars, soos Grossarth, Karoofossiele na Duitsland gestuur. Ook Amerikaanse vakgeleerdes, soos Case, Romer Camp en Gregory het ons Karoo besoek en materiaal na die Verenigde State meegeneem en ook Dr. Broom het nog verskeie versamelings daarheen en na Londen gestuur. Prof. Watson van Londen en Mnr. Parrington van Cambridge het ook nog materiaal van Suid-Afrika verkry. Ondertussen het egter die versamelings aan Suid-Afrikaanse Museums, veral die te Kaapstad, Bloemfontein, Pretoria en Grahamstad geweldig gegroei sodat die versamelings in die buiteland nie meer die belangrikste is nie.

Daar is gedurende die laaste kwart eeu verskeie male vertoë tot die owerheid gerig om die uitvoer van ons Karoofossiele te beheer—tenminste tweekeer deur hierdie Vereniging—en het daar toe eindelik beherende wetgewing tot stand gekom soos vasgelê in Wet 4 van 1934, Wet 9 van 1937 en deur die Regeringskennisgewings Nos. 1571 en 1572 van 1938.

Op die oomblik is daar voltydse palaeontoloë aan die Museums te Kaapstad en Pretoria en 'n deeltydse te Bloemfontein werksaam. Die ander Museums werk ook, tot 'n sekere mate, mee, asook die Geologiese Opname.

Korteliks wil ek my nou besig hou met die vraag: Watter invloed het die ontdekking en ondersoek van die Karoofauna op die biologiese wetensakpppe uitgeoefen? Bain se ontdekking van reptielfossiele in Suid-Afrika het plaasgevind op 'n baie interessante, byna kritieke, tydstip in die geskiedenis van die palaeontologie en dus ook van die geologie en die dierkunde. Dit het plaasgevind slegs één jaar na die dood van William Smith—die vermaarde Engelse aardkundige, wat die stelling in die geologie ingevoer het dat die verskillende rotslae mekaar op 'n bepaalde manier opvolg en dat die verskillende sedimentêre lae gekenmerk is deur 'n bepaalde fossiele-inhoud d.w.s. die idee van Leitfossilien. Charles Lyell was toe in die middel van sy geologiese ondersoekinge wat hom tot die gevolgtrekking gebring het dat die bestaande aard en vorm van die aardoppervlakte deur 'n geleidelike ontwikkelingsproses ontstaan het. Hierdie geologiese opvatting van ontwikkeling in die aardkors het 'n groot invloed uitgeoefen op die dierkunde wat toe, veral deur Lamarck se idees van die ontwikkeling van diere, in 'n oorgangstadium verkeer het. Dit is dan ook natuurlik dat Lyell later, en wel in 1861, 'n werk ter ondersteuning van Darwin se Ontwikkelingshipotese laat verskyn het.

Nie alleen het die geologie as selfstandig en gegronde wetenskap ten tye van Bain se ontdekking tot stand gekom nie maar was ook die fossielkunde so pas as wetenskap gegrond. ·Fossiele was al aan die Grieke bekend en het baanbrekers soos da Vinci, Buffon, Bonnet, Blumenbach, Lamarck e.a. hul aandag al aan die fossiele gewy, maar dit was eers die genie van Cuvier (1769-1832) wat die grondslag gelê het van ons moderne opvatting van fossiele. Cuvier het nl. in sy ,, Regné Animal " die fossiele diere

ook in die zoologiese sisteem ingeskakel en in sy ,, Recherches sur les ossemens fossiles " (1812) getoon dat hy die soogdierfossiele van die Paryse bekken sistematies uitgegrawe het en nie net stukkies en brokkies versamel het nie. Ook is daar sorgvuldig aandag geskenk op die lae waar die verskillende fossiele in voorkom d.w.s. hul stratigrafiese posisie is vasgestel. Deur hierdie werk van Cuvier het die fossielkunde 'n geweldige stoot vorentoe gekry. Ongelukkig egter ontwikkel Cuvier sy berugte Katastrofeteorie, wat stremmend gewerk het op die verderontwikkeling van die ontluikende ontwikkelingsleer en die palaeontologie, want so groot was Cuvier se gesag in die jong wetenskap, dat sy leerlinge en volgelinge gehuiwer het om te vat aan die idees van Lamarck en later ook die van Darwin.

Ons sien dus dat die palaeontologie as gegronde vak slegs 26 jaar gevestig was toe Bain sy eerste fossiele uit die Karoorotse gekap het.

In Engeland was Richard Owen (1804-1892) die leier van die jong palaeontologiese wetenskap. Hy was ondersteuner van Cuvier se Tipeteorie en was sterk gekant teen die idee van 'n ontwikkelingsreeks vir die diere in die opmekaarvolgende rotslae. Met die verskyning van Darwin se ,, Origin of Species " was hy dadelik 'n hewige teenstander, en voer 'n hewige en anonieme polemiek teen Darwin en sy kampvegters Huxley en Haeckel. Bain se besendings van Karoofossiele kom in die hande van hierdie uitmuntende dierkundige en die grootste Engelse vergelykende anatoom van alle tye, maar soos ons gesien het, 'n persoon wat, so nie as reaksionêr, dan wel as sterk konserwatief bestempel moet word. Dit is dus te verstaan dat Bain se fossiele in Owen se hande meesterlik van vergelykendanatomiese standpunt ondersoek en beskrywe was, maar hul unieke posisie in die ontwikkelingsreeks van die werweldiere is nie besef nie. Ook Huxley, die groot kampvegter van die ontwikkelingsleer, het nie die soogdieragtige Therapsida as naverwante van die voorouers van die soogdiere herken nie, daar hy verblind was deur sy geloof in die Amphibiërafkoms van die soogdiere—'n hipotese wat destyds sterk ondersteuning van die vergelykende anatomie en embriologie geniet het. Deur die gesag van Owen se opposisie en Huxley se dwaling is aan die Therapsidareptiele van Suid-Afrika gedurende Bain se lewe nie hul regmatige phylogenetiese posisie toegeken nie. Dit het eers plaasgevind toe Cope, in Amerika, in 1870 die sterk soogdierkenmerke in 'n Suid-Afrikaanse Anomodontiërsedel raaksien. Vanaf 1875 het Cope ook die soogdiereienskappe in die geraamte van die Amerikaanse Pelycosauriërs opgelet. In 1876 het Owen ook gedeeltelik bekeerd geraak en het hy op so 'n verwantskap gesinspeel.

Omtrent op hierdie tydstip is ook die eierlêende soogdiere van Australië, veral deur die ondersoekinge van die Duitser, Semon, beter bekend geraak. Die wetenskaplike ondersoek van hierdie diere het aan die idee van 'n reptielafkoms vir die soogdiere 'n groot stoot vorentoe gegee sodat selfs Owen in 1889 die moontlikheid uitspreek dat die Monotremata direkte afstamme-

linge van die Suid-Afrikaanse Therapsida is. Deur sy ondersoekinge oor die Pelycosauriërs van Amerika oortuig, het Cope in 1884, hom baie definitief uitgespreek ten gunste van die reptielafkoms en teen die amphibiërafkoms van die soogdiere.

Dit is omtrent hierdie tyd (1889) dat Seeley sy versameltog in die Karoo onderneem het en o.a. 'n geraamte en heelwat skedels van Cynodontiërs—een van die mees soogdieragtige Therapsida-groepe-hoofsaaklik met die hulp van T. Bain, Kannemeyer en Alfred Brown—vir ondersoek verkry het. Seeley het baie van die soogdieragtige kenmerke van die Cynodontiërs raakgesien, maar was meer geneig om dit as 'n geval van parallelle ontwikkeling te beskou. Seeley, wat toen ter tyd onder die invloed van die idees van Mivart gestaan het, het in die tyd begin praat van 'n diphiletiese oorsprong van die soogdiere nl. dat die Monotremata en die hoër soogdiere apart onstaan het.

Die ondersoekinge van Osborn, Baur en Case vanaf 1888 en veral 1897, wat ook beinvloed is deur hul kennis van die Amerikaanse Pelycosauriërs, het die idee van die Therapsida-oorsprong van die soogdiere op vaste basis geplaas. Baur en Case sê in 1897, ,, We are fully convinced that among these South African forms . . . . we have those reptiles which might be considered as ancestral to mammals or at least closely related to their ancestors ''.

Toe Broom in Suid-Afrika begin het met sy werk op die Karoofossiele het hy die groot voorsprong gehad dat hy in Australië eerstehandse kennis van die laagste soogdiere, die Monotremata en Marsupialia, gehad het, en was die stap na die hoogste soogdieragtige reptiele dus natuurlik en ook vrugbaar. Gedurende meer as veertig jaar van ondersoek het Broom hom besig gehou met die probleem van die ontstaan van die soogdiere vanuit die Therapsida. As voorvaders van die soogdiere beskou hy eers die Cynodontiërs, toe die Bauriamorpha en sedert 1929 die sg. Ictidosauria.

Watson, Haughton en van Hoepen het hul werk op die Karooreptiele begin toe die algemene mening die Cynodontiërs as die voorvaders van die soogdiere aangewys het. Watson het vroeg al (1913) die neiging openbaar om beide die Cynodontiërs en die soogdiere van Therocephaliërs of pro-Therocephaliërs af te lei en om 'n groot mate van parallelle ontwikkeling by die verskillende orders van die Therapsida in 'n soogdierrigting te vermoed.

Bostaande uiters beknopte oorsig laat dit tog deurskemer dat die eerste vyftig jaar van ondersoek van ons Therapsida, gepaard natuurlik met vergelykend-anatomiese werk (Gegenbaur, Fürbringer, e.a.) en ook embriologiese navorsing, soos veral die van Parker en Gaupp, die dierkundiges oortuig het dat die soogdiere van die Therapsida afgestam het. In die volgende vyftig jaar het ons kennis van die verskillende ordes van die Therapsida geweldig uitgebrei, en dit tot so 'n mate dat ons in al die groepe so 'n tendens tot die soogdieragtige bemerk dat slegs nog

meer tussenvorme die juiste ontwikkelingstrappe kan aandui. Vandag is ons daar meer van oortuig as ooit dat die soogdiere afstammelinge is van reptiele, maar juis watter stadia 'n direkte afstammingsreeks uitmaak kan ons vandag nog nie met sekerheid bepaal nie.

Alhoewel die Suid-Afrikaanse Karoofauna veral belangrik is vir die ontrafeling van die probleem van die ontstaan van die soogdiere, het sekere ontdekkings in die Karoorotse ook heelwat lig gewerp op die ontwikkelingsgeskiedenis van ander werweldiergroepe. Ons dink aan *Eunotosaurus* in verband met die beginstadia van skilpadontwikkeling; die Pseudosuchiërs met betrekking tot die ontstaan van Dinosauriërs en voëls; die Pelycosimiers as naverwante aan die voorouers van die krokodille; die Eosuchiërs in verband met die ontstaan van die Rhynocephaliërs, en *Prolacerta* kom ook in betrag by die ontrafeling van die oorsprong van die akkedisse. Vir die ontrafeling van verwantskappe van die verskillende lewende en uitgestorwe reptielgroepe, *inter se*, speel ons Karoofauna natuurlik 'n baie belangrike rol.

Nieteenstaande die feit dat ek in hierdie rede my hoofsaaklik beperk het tot die fauna van ons Karoorotse is dit nodig, indien ons ons perspektief wil behou, om rekenskap te hou met die ontwikkeling van die kennis aangaande die verwante fossiele reptiele van die Perm en Trias van ander wêrelddele.

In Europe is die vondse van 'n Cotylosauriër-Pelycosauriërfauna meer van palaeozoölogiese belang. Von Meyer se eerste beskrywings dateer 1838 en is opgevolg deur Fitzinger in 1840. Gaudry in Frankryk het verskeie vorms tussen 1874 en 1901 beskrywe; Fritsch in 1895 en von Huene vanaf 1902. Belangrik sowel van morphologies-phylogenetiese as van zoögeografiese aspek is die ontdekkings in Rusland, beskrywe deur de Waldheim in 1840-1846, Twelvetrees in 1880, Trautschold in 1884, Seeley in 1889 en Amalitzky in 1900. In die jongste tyd is 'n uitgebreide Therapsida fauna vanuit Rusland en ook 'n paar vorme van Sinkiang in Chinese Turkestan bekend geraak deur die ondersoekinge van Sushkin, Hartmann-Weinberg, Pravoslavlev, Riabinin, Efremov, Yuan, Young e.a.

By Elgin in Skotland is ook 'n klein fauna van Cotylosauriërs, Therapsida en Rhynchocephaliers ontdek. Die eerste beskrywing is die van Mantell (1852), opgevolg deur referate van Huxley (1867) en Newton (1892).

Uit Voor-Indië is 'n paar Anomondontiërs bekend deur die beskrywings van Huxley (1861), Lydekker (1879) en Blanford (1884). Uit Frans-Agter-Indië is 'n Anomondontiërfragment beskrywe deur Repelin (1923).

In Noord-Amerika is 'n uitgebreide fauna van Cotylosauriërs en Pelycosauriërs bekend en in die jongste tyd ook vorme baie naverwant aan ons Suid-Afrikaanse soorte. Die vernaamste ondersoekings daar is gedaan deur Leidy (1853), Lea (1856),

Marsh (1878), Baur en Case (1897), Osborn (1898), Williston (1904), Broili (1904) en in die laaste kwart eeu deur Gregory, Romer, Camp e.a.

Sedert 1928, toe von Huene 'n versameltog na Suid-Amerika onderneem het, is 'n goed-verteenwoordigende Therapsida-fauna, met ook Rhynchosauriërs daarby, van Argentinië en Brazil bekend. Die ondersoek van hierdie Suid-Amerikaanse fauna sal in die toekoms sekerlik nog baie interessante en belangrike gegewens ter ontrafeling van die ontstaan en ontwikkeling van die soogdieragtige reptiele oplewer.

In Afrika is ook gevind dat die Therapsida-fauna meer verspreid is as wat vroeër gemeen is. In Rhodesië en in Tanganjika is interessante vorms van Cotylosauriërs, Therapsida en Thecodontiërs ontdek deur Stockley, Dixey, Hennig en Parrington wat deur laasgenoemde en deur Haughton en die skrywer beskrywe is. Von Huene is ook tans besig om, saam met Parrington, Hennig se onlangse versameling te ondersoek. Dit wil dus blyk dat, wat ons vroeër as 'n bykans unieke Suid-Afrikaanse fauna beskou het, oor groot en wydverspreide dele van die aardbol versprei is. Hierdie aspek open dus baie interessante zoögeografiese probleme waarby die geoloë, plantkundiges, geograwe en metereoloë hul bydraes sal moet lewer. Die palaeontologie is dus verreweg nie 'n onderwerp so droog soos die bene waaroor dit behandel nie. Die suiwer vergelykendosteologiese sy verteenwoordig verreweg nie die hele palaeontologiese wetenskap nie! Dit is slegs die fondament waarop, met behulp van die verwante wetenskappe, ons totale kennis van die aard van vergange eeue moet staan.

Die palaeobiologiese aspek van die Karoofauna het nog betreklik min aftrek gehad. Weliswaar het iedere navorser, en hier dink ek veral aan Watson en Broom, al terloops sekere waarnemings gemaak maar dit is slegs Case, Haughton en von Huene wat 'n bietjie dieper die terrein betree het. Wat die sagter weefsels, bv. die spiere, betref lê daar ook nog 'n braakland. Slegs Gregory, Camp, Romer en die skrywer het al so 'n bietjie aan hierdie onderwerp gepeusel. In die toekoms sal hierdie aspekte nog 'n vrugbare arbeidsveld oplewer. 'n Palaeontoloog met die vereiste verbeeldingskrag en die bepaalde skrywersvaardigheid, of miskien nog liewer 'n romanskrywer met die nodige palaeontologiese kennis, sal nog vir ons 'n groot werk oor die lewe van die Karoodiere van 250 miljoen jaar gelede kan skrywe—'n Suid-Afrikaanse Palaeo- „ Oerwoud en Vlakte ". Om u 'n idee te gee van die aangrypende aard wat so 'n werk oor die lewe van die Karootydperk kan aanneem gee ek 'n skematiese raamwerk.

As u kan terugdink in die grysverlede na 'n tydperk 250 miljoen jare gelede sal u 'n land sien wat hemelsbreed verskil van die huidige Suid-Afrika. In die middel van die Suid-Afrikaanse subkontinent sien u 'n enorme laagliggende, grotendeels moerasagtige, kom.

As u dit sou vergelyk met die kaart van die huidige Suïd-Afrika sal u oplet dat die rante van hierdie enorme kom ooreenslaan met lyne wat ons moet trek van Oos-Londen na Laingsburg, vandaar deur Nieuwoudtsville na Kenhardt, dan na Kimberley, en vandaar na Middelburg, Transvaal, en dan weer suid na Vryheid en vandaar deur Greytown en Pietermaritzburg na Port St. Johns.

Kyk ons nou buite die rante van die groot Karoomoeras sal ons sien dat ten ooste Suid-Afrika verbind is met Indië en Madagaskar, ten noorde was daar bergreekse waar vandag Windhoek, Grikwaland Wes en die noordelike Transvaal lê, en ten weste was Suid-Afrika verbind met 'n landmassa waar die huidige Suid-Atlantiese Oseaan lê—dit is vandag Suid-Amerika.

Sulks was die algemene geografiese toestande toe die Karootydperk aangebreek het.

Van die berge ten noorde, ten suide en ten ooste het spruite en riviere afgestroom na die Karookom. Die sand, modder en silt wat hul afgespoel het is oor die bodem van die moeras versprei. Laag na laag sediment is op hierdie manier neergelê, sodat, in the suide waar die Karookom die diepste was, na etlike duisende jare die dikte van hierdie lae silt omtrent 800 voet bedrae het.

Dit was egter nie lank nie of die klimaat het geweldig verander. Die temparatuur het al hoe laer geword totdat die groot Dwyka-Ystydperk die Karoo oorweldig het. Van die berge ten noorde en ooste het gletsers die Karookom binnegedring en geweldige ysblokke in die Karoomeer neergestort. In so 'n onverbiddelike wêreld kon byna geen plant of dier bestaan nie. Die gletsers wat van die berge afgekruip het, het modder, grond en klippe van die berge afgeskeur en saamgesleep. Stadig het die yskoue blokke gesmelt en die modder en klippe het na die boom van die meer gesak en laag op laag tot 'n dikte van 1,000 voet is so opgebou.

Hierdie Ystydperk het honderde duisende jare geduur maar mettertyd het die klimaat begin warmer word en met die smelt van die ys is daar 'n groot gewig van die land ten ooste afgeneem sodat daar 'n bergreeks opgedruk is. 'n Nuwe tydperk — die Eccatydperk — breek nou aan. Alhoewel nog koud het die ys verdwyn, die klimaat was baie nat en reënerig met die gevolg dat ontsettende massas van sand en modder van die berge afgespoel het en op die bodem van die Karookom versprei is tot 'n dikte van 6,000 voet. Die effens milder klimaat het die bestaan van plante moontlik gemaak en weldra was daar oor die hele Karoo 'n eienaardige plantegroei versprei. Dit het bestaan uit eienaardigte soorte varings, perdesterte, mosse en dergelyke laagontwikkelde plante, maar ook veertig voet hoë boomvarings wat op palme gelyk het. Die Ecca plantegroei was baie weelderig en het ontstaan gegee aan byna al ons Suid-Afrikaanse steenkoollae. Op die plante het daar allerlei insektagtige diere rondgekriewel en in die water was daar paddaslym, visse en skulpdiere.

So het etlike duisende jare verbygegaan. Die klimaat het nog warmer geword, die ontsaglike reënval het verminder sodat die mere en moerasse geskei was deur stroke hooglêende hoogland bedek met harder en meer veselagtige plante. Die Beauforttydperk het nou aangebreek en ons bemerk dat van die landmassa, wat ten suidweste van die Karoo geleë was, 'n gestadige immigrasie van allerhande koddige kruipende gediertes van soorte wat ons vandag glad nie ken nie, die Karoo binnetrek. Van ons huidige bekende kruipende gediertes, voëls en soogdiere was daar geen enkele verteenwoordiger nie. Die werweldiere het slegs bestaan uit eienaardige primitiewe paddasoorte en hoogs interessante soogdieragtige kruipende gediertes soos die plantetende Pareiasauriërs, Dicynodontiërs en Tapinocephalide, die vleesetende Therocephaliërs en Gorgonopsiërs.

Kyk ons so terug na die Oudste Beauforttydperk sien ons 'n hele tafereel sig afspeel: 'n hele klompie Pareiasauriërs is hier op die voorgrond; hul is groot, massiewe, lomp diere omtrent 12 voet lank en 4 voet hoog en oor hul hele rug het hul vir beskerming 'n harnas van benige plaatjies; party wei op die walle van 'n moeras in 'n pol ruig varingagtige plante, 'n paar swem lui in die water rond soos seekoeie, en 'n ou mannetjie lê op 'n sandwal en bak in die son soos 'n krokodil. Kyk ons op na die hoër grond sien ons groepies minder lomp maar nog steeds massief geboude Tapinocephalide wat wei op die minder sappige en meer veselagtige plante van die hoogland. Kyk ons noukeuriger dan bemerk ons dat tussen die rhenosteragtige Tapinosephalide daar 'n hele trop kleiner en ratser diere rondwei. Hul is die Dicynodontiërs. Dis tog te koddig om te sien hoe hul wei—die kop word so skuins gehou en met hul skilpadagtige bek sny hul op hul onbeholpe manier die blare van die harde veselagtige plante af. Skielik word die vrede gesteur.

'n Lompe Pareiasauriër, wat ver van die water afgedwaal het, waggel so vinnig soos sy stomp koddige bene, wat so ver van sy lyf afstaan, hom kan dra af water-toe en plons pardoems, daarin soos die moderne seekoei dit alleen kan nadoen. Die groot Tapinocephalide draf met groter behendigheid die ruigte in. Die Dicynodontiërs laat spat party soos groot rotte, ander groter soorte minder rats en meer waggelend die varingbossies in vir skuiling. Almal is onder skuiling. Maar nee! Een ou Pareiasauriër het 'n bietjie te ver van die water afgedwaal en hy maak dit nie! 'n Ratse roofdier—'n Therocephaliër wat vir sulke onverskilligheid gelê en wag het loop hom in. 'n Finale sprong en hy sit op die Pareiasauriër se rug. Sy skerp kloue sny in sy slagoffer se rug en sy skerp slagtande sak in sy nek. Die Therocephaliër se wyfie is nou ook by en dit duur nie lank nie of hul het hul buit neergetrek, en na so 'n paar slae rondkyk begin die twee roofreptiele hul maal.

Die alarm is verby en versigtig kruip die Pareiasauriërs en Dicynodontiërs hul skuilplekke uit en is hul weldra weer aan 't wei en die tragedie van flussies is heeltemal vergeet. 'n Pareiasauriër waggel so wrintig waar al hoe verder die sandwal

uit. Hy is so vreeslik in die sand geinteresserd—hy krap 'n bietjie rond—gaan 'n entjie verder en begin dan weer grawe—net soos 'n skilpad dit doen. Nou is hy tevrede—hy grawe al hoe dieper—stadig, onbeholpe maar metodies. Hy beweeg 'n paar slae om die gat—grawe nog 'n bietjie en draai heeltemal weg. Was al die werk dan verniet? Nee. Hy kom terug gat-toe, maar nou agterwêreld voor. O, so! dis 'n „ sy " nie 'n „ hy " nie. 'n Groot eier kom te voorskyn en word versigtig op sy plek in die gat gestoot—'n pouse—nog 'n eier en dan nog een. 'n Half uur het verstryk en tien eiers is versigtig in die gat gestop, met sand toegemaak en vasgestamp. Sy draai nog so 'n paar slae om die plek en tevrede dat dit goed verskuil is waggel sy weer terug na haar geliefde moeras. Wat van die eiers? O, vir hul sal die son sorge en as g'n Gorgonopsiër of Theropcephaliër die nes uitgrawe nie dan is daar oor 'n tydjie weer tien bollige Pareiasauriërtjies in die wêreld.

Nog 'n paar miljoen jaar later en ons vind dat die Pareiasauriërs en Deincephaliërs en baie Dicynodontiërs, Gorgonopsiërs en Therocephaliërs uitgestorwe is. Die lyke van die diere wat gedurende hierdie eeue doodgegaan het, het in meeste gevalle vergaan maar van party het die geraamtes in die modder vasgeval en is toe bedek deur die volgende laag modder. So is laag op laag van modder opgebou totdat party van die geraamtes duisende voet onder die oppervlakte begrawe was.

Ons is nou in die middel van die Beauforttydperk. Die werweldiere bestaan hoofsaaklik uit varswater visse, tweelewige Amfibiërs, waterlewende Lystrosauriërs en vleesetende Cynodontiërs. Die klimaat was vogtig met periodieke oorstromings en die laaglêende Karoo was vir die grootste gedeelte van die jaar een groot uitgestrekte moeras maar gedurende sekere tye was dit egter droer. In hierdie waterryke wêreld het die waterlewende Lystrosauriërs gefloreer. Hul was kruipende gediertes omtrent so groot soos 'n baie jong seekoei met die neusgate ver na agtertoe verskuif weg van die snoet af. Hul lewenswyse was baie soos die van die seekoei alhoewel hul nie so goed op droë grond beweeg het nie. Hul het gewei op die sappige waterplante en wortels en op die geringste teken van gevaar het hul veiligheid in die water gesoek waar hul ook verder die lewe speelspeel geslyt het. Op die droë grond het die Cynodontiërs gelewe. Hul het goed ontwikkelde ledemaatsgewrigte besit en het vinnig en rats beweeg amper soos ons huidige soogdier-roofdiere soos tiers en leeus. Hul. prooi het grotendeels bestaan uit die weerlose Lystrosauriërs. Gedurende hierdie tydperk het daar immigrante uit Europa ingekom. Hul het Europa verlaat, die Tethys oseaan (geleë omtrent waar die Middellandse oseaan vandag is) oorkruis en langs die ooskus van Afrika afgetrek en hul in die Karoo gevestig. Hierdie eerste setlaars in Suid-Afrika was klein akkedisagtige Procolophoniërs en hul naaste verwante word in rotse in Sentraal-Europa aangetref. Wat die ekonomiese toestande was wat hul daartoe gedryf het om huis en haard te ver-

laat en die lange gevaarlike reis te onderneem is onbekend. Miskien was dit 'n innerlike dryfkrag—'n Wanderlust.

Nog 'n paar miljoen jaar het verstryk en ons bevind ons in die Jongste Beauforttydperk. Die klimaat is nou afwisselend reënagtig, maar by tye baie droog en dor. Die plantegroei bestaan uit mosse, varings, perdesterte, ginkgoes, kegeldraende plante en bome ens. maar nog geen grassoorte of ander blomdraende plante nie. Sommige plantende skilpadagtige Dicynodontiërs kom nog voor—party soos *Kannemeyeria* was so groot soos 'n jaar oud rhenoster. Hul vyande was die roofdiere—die Cynodontiërs—met hul sterk slagtande. Gelyktydig kry ons die Bauriamorpha—klein kruipende diertjies wat baie soos 'n hond gelyk het, alhoewel die een 'n reptiel en die ander 'n soogdier is. Ook kom *Euparkeria* voor—dit is ook 'n reptiel maar hy begin al baie op 'n voël lyk.

Hierop volg na etlike duisende jare die Rooibeddenstydperk. Die klimaat was droog en dor met periodieke oorstromings. In hierdie halwe-woestyn tref ons verskillende soorte reptiele aan en dit is baie interessant om op te merk dat hul omtrent almal lang en slanke pote gehad het soos ons huidige woestyndiere ook besit. Dit het hul nodig gehad om vinnig van plek tot plek te gaan om genoeg voedsel en water te kry. Die diere is hoofsaaklik klein Cynodontiërs, middelmatige Dinosauriërs en die eerste bekende klein soogdiere. Die Dinosauriërs het vanuit Europa gekom—al langs die ooskus van Afrika. Die Dinosauriërs was vinniglopende ratse diere wat hoofsaaklik op hul agterpote gehardloop het en hul voorpote was voorsien van sterkgeboë kloue wat hul gebruik het om hul prooi mee te vang.

Nou kom ons by 'n tydperk omtrent 150 miljoen jaar gelede—die Grootsandsteentydperk—'n tydperk van droogte, woestyn en uitgestrekte streke van sand heen en weer gewaai deur die wind. Hierdie sand is oor die bodem van die kom versprei tot 'n dikte van 800 voet. Die Karookom was nou nie meer baie diep nie. Dit het al begin vol raak van al die afsaksels. Al die reptiele is liggeboude diere met lang dun pote geskik vir sulke woestynomstandighede. Hier kom geen diere voor wat lief is vir, en aangepas is aan 'n moeraslewe nie. In hierdie ongasvrye wêreld het die eerste klein soogdiere gelewe en dis waarskynlik dat dit juis die swaar en moeilike lewe was wat die eerste soogdiere aangespoor het tot groter inspanning en adaptasies om die stryd vir die bestaan moontlik te maak.

Alreeds gedurende die Rooibeddenstydperk het daar af en toe vuurspuwende berge voorgekom. Hierdie uitbarstings van vulkaniese aktiwiteit het nou al hoe meer toegeneem en uiteindelik het hierdie uitbarstings op so 'n groot skaal plaasgevind dat dit, saam met ander faktore, 'n eind gemaak het aan die Karooperiode van Sedimentasie.

Die Karooperiode het dus begin met 'n onverbiddelike yskoue klimaat en het ten einde gekom te midde van die ontsaglike uitbarstings van vuurspuende berge.

As 'n mens dink aan die vordering wat in die meeste wetenskappe gemaak is dan kom die verbetering in tegniese vaardigheid en toerusting dadelik in die gedagte op. Dink maar aan die mikroskoop in die biologie, die spetroskoop in die fisiese wetenskappe, verdowingsmiddels in die medisyne, ens. In die palaeontologie het apparaat en metodiek nie 'n groot rol gespeel nie. Sedert Bain 'n honderd jaar gelede die eerste fossiel in die Karoo uitgegrawe het is daar geen besondere verbetering in die metodiek en die tegniese hulpmiddels te bespeur nie, maar in sekere opsigte wel agtuitgang. Bain, Atherstone, Rubidge, Brown, Whaits en die ander ouer versamelaars, alhoewel geen wetenskaplik opgeleide fossielkenners nie, het 'n aangebore wetenskaplike gees openbaar. Geeneen van hul sou vir gewin versamel nie. Ook sou hul dit as heiligskennis beskou het om alleen skedels te versamel en die ander dele van die geraamte te laat lê. Ook sou hul geen geraamte met pikke en koevoete uitruk, en die uitgebreekte stukke onsistematies in kiste ingooi en op die trein smyt nie. Hierdie soort metodes is van jonger datum. Dit is merkwaardig hoe min volledige geraamtes in die Karoo verkry is. Die aard van die voorkoms van die fossiele is egter alleen ten dele daarvoor verantwoordelik. Die metodes van opgrawing kan baie verbeter word! Van die groot Pareiasauriërs, waarvan die geraamtes gewoonlik volledig begrawe is, is slegs 'n tien jaar gelede die eerste volledige geraamte opgegrawe volgens 'n metode soos voor hierdie Vereniging te Barberton voorgedra is. Die metodes van versameling en opgrawing is vir die bevordering van die wetenskap net so belangrik as die navorsing op die versamelde materiaal. Die versameling van fossiele dien veral die vergelykende anatomie en dit moet nie toegelaat word dat dit in 'n soortjag ontaard nie. Die preparering van die Karoofossiele het ook al baie te wense oorgelaat sodat baie vorms heeltemal onvolledig beskrywe en afgebeeld is en dus van vergelykendanatomiese standpunt van min waarde is, nieteenstaande hul heeltemal geldig is as sg. nuwe tipes. In hierdie verband kan ek nie nalaat om aan Proff. Broili en Schröder en hul preparators Kochner en Haimerl, en die tekenaar Dr. Erhardt lof toe te swaai vir hul voorbeeldige reeks referate oor die Karoofossiele in hul versameling. Iedere eksemplaar is pragtig geprepareer, volledig beskrywe en tekeninge van alle sye helder die beskrywings op. Verder word 'n eksemplaar afgeteken soos dit bewaard is en dan word daarby nog gerekonstrueerde tekenings verskaf. Daar die gesteentes van ons Karoo soms besonder hard is, is die gewone prepareringsmetodes soms onuitvoerbaar en is dan die metode van seriesnitte soos deur Sollas en Sollas in 1913 vir 'n Dicynodontiërskedel aangewend sterk aan te beveel veral by skedels wat uitwendig verweerd is maar waar die inwendige struktuur van morphologiese belang is. Daar is al verskeie pneumatiese beitels aangewend vir fossielpreparering maar dit skyn asof hierdie apparate slegs in besondere gevalle doeltreffend is.

In ons geskiedkundige oorsig het ons gesien hoe ons kennis van die Karoo uitgebrei het en watter groot rol die gespeel het by die grondlegging van ons groot biologiese beginsels. Laat ons 'n bietjie stilstaan by die tekortkomings. Die Karoorotse het al verassende diere opgelewer, nie alleen wat individuele kenmerke betref nie maar ook vorme wat belangrike morphologiese probleme ophelder. By ieder nuwe ontdekking gaan daar 'n nuwe lig op, maar, wat so tergend is van die vondse in die Karoo, is dat die ontdekkings as 't ware die sluier effens oplig, sodat ons 'n algemene blik van die verwantskappe en samestelling van die diere kry en dan sak die sluier weer; sodat ons slegs 'n idee kry van die algemene strekking van die ontwikkelingsrigting, sonder dat ons egter die individuele stappe kan beken. Dit is tipies van Afrika! Dit belowe so veel, maar so baie word agtergehou.

In Suid-Afrika het ons massale sedimentêre rotslae wat konkordant opmekaar volg tot 'n dikte van oor die 26,000 voet, en 'n tydperk—van die Dwyka tot by die Stormberg—wat 'n periode van oor die 100 miljoen jaar beslaan. Die Dwyka- en Eccalae, gesamentlik by die 9,000 voet dik, dus 'n derde van die totaal, het tot dusver nog geen noemenswaardige werweldiere opgelewer nie. En hierdie lae is neergelê gedurende 'n periode in die ontwikkelingsgeskiedenis van die hoër werweldiere wat juis van ontsaglike belang is. Dit is gedurende hierdie periode dat die verskillende reptielgroepe vanuit die stamgroep van die reptiele gespruit het. Van hierdie ontstaan leer die Karoorotse ons tot dusver nie veel nie en moet ons waarskynlik in ander wêrelddele gaan soek vir die beginstadia van ons reptielfauna. In die Beaufortlae tref ons dadelik byna al die hoofreptielgroepe aan. Dit is asof die Natuur ons wil uittart deur te sê, ,, Hier het julle nou die tweede bedryf, en van wat daar voorkom en afgespeel word moet jul maar die eerste bedryf rekonstrueer, of, as jul dit nie kan doen nie, sal jul moet gaan na die plek waar die eerste bedryf wel afgespeel is. Kry daardie plek as jul kan ''.

By die aanbreek van die ontwikkelingsgeskiedenis, soos in die Karoorotse openbaar, tref ons die Pareiasauriers, Deinocephaliërs, Anomondontiërs, Therocephaliërs, Gorgonopsiërs, Dromasauriërs en Protorosauriërs as gevestigde dierordes aan, en om hul onderlinge verwantskappe vas te stel kan ons ons alleen op vergelykendanatomiese oorwegings beroep, terwyl die palaeontologie hom juis liewer beroep op die werklike diere in ouer rotse gevind.

Oënskynlik is ons daar beter aan toe wat die jonger groepe soos die Cynodontiërs, Bauriamorpha e.a. betref want ons ken immers die fauna van die onmiddelik ouer rotse. Die ondervinding leer egter dat ons hier nog steeds die leemte voel van ons gebrek aan kennis van die struktuur van die pro-Therocephaliërs en die pro-Gorgonopsiërs. Maar hier lok die Karoo ons steeds aan, want die moontlikheid bestaan dat ons in die Onder-Beaufortlae wel nog primitiewe Therocephaliërs en Gorgonopsiërs kan vind.

Met sy Therocephaliërs, Bauriamorpha en Cynodontiërs gee die Karoo ons die algemene aanduiding van die ontwikkelinsrigting van die soogdierwording aan en dan, om ons te tempteer, lewer hy ook 'n werklike soogdier, soos *Tritylodon*, maar die werklike tussenstadia moet ons nog versamel.

Die Deinocephaliërs vind ons slegs in die onderste sone van die Beaufortlae en die Pareiasauriërs slegs in die Onder-Beaufortlae. Hul het totaal uitgesterf. Die waarom van sulke uitsterwing bied 'n hele navorsingsterrein aan. Ons weet dat hierdie diere sterk gespesialiseerd was—die geraamtes veral het swaar en lomp geword—maar om te sê dat hul weens hul spesialisasie uitgesterwe het bring ons nie veel verder nie. Ons wil die besonderhede weet. Vir watter veranderde omstandighede was hierdie spesialisasie so ongunstig; het hul miskien die prooi geword van parasiete; het konkurente opgetree, of roofdiere tot stand gekom of het daar iets met hul voedselvoorraad gebeur weens plantsiektes, droogtes, ens. ?

Vir die student van aanpassingsvermoë bied die Karoofauna 'n ryk arbeidsveld. Ons weet dat hierdie reptiele destyds die hele hoër werweldiere beheers het. Daar was vorms wat die rol van ons huidige roofdiere soos leeus, ties, wolwe, ens. gespeel het; soorte wat die plek van ons herbivore antilope inneem; insekvreters wat optree soos sommige van ons huidige reptiele en kleiner soogdiere; ons weet selfs van een giftige soort wat ons aan die huidige slange laat dink; die Dicynodontiërs het 'n bek en voedingswyse wat ons laat dink aan ons moderne skilpaaie; die Lystrosauriërs herinner aan die lewenswyse van ons seekoeie Al hierdie reptiele—in baie opsigte nog van primitiewe struktuur en van 'n lae ontwikkelingstrap—was destyds heeltemaal goed genoeg uitgerus en het die aanpassingsvermoë besit om in die wêreld op te tree, soos slegs die soogdiere hul dit kon nadoen. Waarlik 'n interessante tema vir breedvoerige behandeling!

So ook gee die Karoofossiele ons 'n ryk morphologiese arbeidsveld en kry ons aanmoedigende blikke in heelwat morphologiese probleme soos die van die temporaalbene, temporaalopenings en jukboë, die prevomer—vomer—parasphenoid—probleem, die alisphenoid—epiptergoid moeilikheid, die Reichertse Teorie, die kwessie van die ontstaan van die multituberkulertande, die sekondêre monddak en ook die probleme in verband met die gordels en ledemate. Maar ook hier is dit net asof die Karoo nie noual al die ontbrekende skakels wil uitlewer nie.

Dit is natuurlik moontlik dat die skakels tussen die verskillende morphologiese stappe en die verskillende diergroepe van so 'n aard was en so 'n lewenswyse gehad het dat hul nie versteen het nie en ons hul dus nooit sal bekom nie. Ons onvolledige kennis in hierdie opsig is egter meer waarskynlik aan ons ondoeltreffende versameling te wyte en hieraan kan en moet die toekoms verbetering bring.

Vandag lê daar in die Karoo honderde fossiele blootgestel aan die oppervlakte van die verwerende rotse wat eenvoudig net opgetel moet word en nog baie ander wat met geringe uitgrawing geberg kan word. Met bostaande wil ek geensins die fantastiese getalle en die ontsaglike snelle verwering soos deur 'n kollega beskryf beaam nie. 'n Goeie saak het geen oordrywing nodig nie! Wat gebeur daar vandag met die fossiele wat deur die natuurlike verwering blootgestel word? Aan die begin van hierdie rede het ek u meegedeel dat daar net drie inrigtings in Suid-Afrika is wat aktief Karoofossiele versamel. Moet hul dan die hele oppervlakte van die Karoo deursnuffel? Onthou die area wat die Karoorotse beslaan is 240,000 vierkant myl—meer as die helfte van die totale oppervlakte van die Unie! Onthou verder dat dit deels deur optrede van hierdie Vereniging is dat buitelandse vakmanne in die toekoms waarskynlik minder in die Karoo sal versamel. Wat staan ons dus te doen?

As dit vir die owerheid nie moontlik is om 'n groter bydrae vir die ondersoek van de Karoofossiele te gee nie dan moet ons ons beperk deur alleen meer geldelike ondersteuning te vra vir die blote versameling. Ek voel daarvan oortuig dat as iedereen van ons tien museums en die afdelings van aard- en dierkunde aan ons Universiteite en Universiteitskollege sê elk bv. £100 jaarliks uitgee op die versameling van Karoofossiele, ons in tien jaar omtrent al die fossiele wat op die oppervlakte lê en gevaar staan om tot niet te gaan in veilige bewaring kan breng. Die preparering, ondersoek en beskrywing kan dan later tydsaam geskied. Na hierdie periode van intensiewe versameling kan daar 'n verslapping intree, wanneer 'n kleiner bende entoesiaste die dele waar verwering die snelste plaasvind jaarliks kan deursnuffel. Behalwe hierdie vakmanne wat aan inrigtings verbonde is moet ons probeer om leke van die kaliber van Bain, Brown, Whaits en die ander ou staatmakers te inspireer. Sulke manne word egter nie gemaak nie maar gebore en kan ons alleen sorg dat hul by hul verskyning die regte aanmoediging kry. Grondeienaars in die Karoo kan egter op die groot wetenskaplike waarde van die fossiele attent gemaak word sodat, alhoewel hulle nie verwag kan word om self te versamel nie, hul die versamelaars na vindplekke kan lei. Ek dink hier aan 'n geval soos die van C. J. Avenant—'n eenvoudige bywoner in die Koup—wat my al na etlike plekke gebring het waar fossiele bene aan die oppervlakte blootgestel gelê het. Die hulp van sulke kenners van die veld moet nie veronagsaam word nie.

Ek vertrou dat bostaande oorsig—die onvolledigheid besef ek ten seerste—nie alleen die vakmanne van ander wetenskappe 'n insig in die palaeontologiese wetenskap soos in Suid-Afrika beoefen gegee het nie, maar dat dit ook hier en daar vir 'n dierkundige en aardkundige 'n nuwe navorsingsterrein wat vrugbare resultate aanbied aangedui het.

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ANTHROPOLOGY AND THE NATIVE PROBLEM

BY

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I.

In these days, when scientists are becoming more and more concerned with the wider social implications of their work, it will hardly be taken amiss by a body, one of whose main functions is to help bridge the gap between the scientist and the layman, if I venture to address you, not on some purely academic topic, but on the part which I, as a social anthropologist, think that my subject ought to play in the public life of South Africa. In doing so I shall but be following the example of my colleagues elsewhere, who for many years now have been repeatedly, and often successfully, insisting upon the practical value of anthropology. It is, in fact, so generally accepted nowadays that a knowledge of anthropology is indispensable in dealing with questions of race relations that I ought rather to apologise for arguing again the case in its favour. But in South Africa there is still need for this, since in few other countries with similar problems has the influence of the anthropologist been so small. It is true that as an academic subject anthropology receives proportionately more attention here than in most other parts of the world, and that facilities for studying it exist at each of our Universities. But in the sphere of practical affairs, and especially of Native policy, where the anthropologist may justly claim some authority, he has so far failed to render all the service that he could. For this he is himself partly to blame, but the Government and the public at large cannot be absolved from indifference and even wilful neglect.

Let me first state briefly the case for anthropological research, considered not as a contribution to science but as an instrument for the promotion of human welfare. In South Africa, as in all other parts of the world where heterogeneous populations live together under a single administration, the study of their respective forms of culture is not only desirable but politically essential. We have here several major groups of peoples—Afrikaners, Britishers, Bantu, Coloured, and Indian, to mention only the numerically most important—whose traditions, languages, and social institutions are often widely divergent. The future welfare of our country demands that we find some social

system in which all these peoples may live together peacefully, without that increasing unrest and ill-feeling that will inevitably develop owing to lack of unity and friendly co-operation. The solution of this problem calls for more than the mere application of conventional administrative principles. It needs to be based upon a sympathetic and thorough understanding of each of the various cultures between which we have to establish harmonious relationships. We can never hope to appreciate the difference between the Britisher and the Afrikaner, the Native, the Indian and the Coloured man, nor can we succeed in our task of reconciling their often conflicting claims and aspirations, until we have studied fully the history, customs, beliefs and ideals of them all. Misunderstanding and lack of sympathy, both due to ignorance, have so frequently led to strife in the past, and are still so powerful a source of friction, that the necessity for knowledge of this kind cannot be sufficiently emphasised. The touchiness of the Afrikaans-speaking European over the slights, real or imaginary, against his language, his traditions, and his political desires is but one manifestation of a tendency which elsewhere has found expression in such phenomena as the Bulhoek affair, the Zulu rebellion, the South African career of Mahatma Gandhi, and the formation of the Dominion Party.

It is here that the anthropologist can be of initial service. His task is to study the different forms of social institution that exist, and to interpret them in the light of the general laws of sociology and psychology. In carrying it out, he relies partly upon the observations of others, but he also spends much of his time making first-hand investigations of his own, by means of which he obtains the factual knowledge upon which theory can be based. Trained in comparative studies of culture and in the methods of observation, and speaking the language of the people among whom he is working, he knows what information to look for, how to look for it, and how to ensure the accuracy of what he records, and while in the field he concentrates upon this one task alone, and has no other occupation to distract him. As a result, he is usually far better qualified than anyone else to provide the knowledge we need for each of the peoples of South Africa.

Hitherto the anthropologist working in this country has confined himself to the study of what we call its Native peoples—the Bushmen, the Hottentots, and the Bantu. He has not yet paid special attention to the cultures of its other inhabitants, whether Europeans, Indian or Coloured. But, let me say at once, there is nothing in the nature of anthropology itself to preclude him from extending his researches to these peoples as well. The idea that anthropology is essentially the study of primitive societies, an idea due to the historical development of the science, is being rapidly discarded. In other parts of the world professional anthropologists are now busy studying not only such comparatively advanced peoples as the Arabs, the Malays,

and the Chinese, but European communities also, especially in Great Britain and the United States. The day will soon some, I hope, when in South Africa too there will be sufficient workers to enable us to do the same for all the different elements in our population.

In the meantime, however, since the anthropologists here have so far restricted their studies to the Natives, I shall for convenience do so too in this address, and show how in my opinion anthropology can assist in solving the special problems that arise from the relations between these Natives, especially the Bantu, and the Europeans governing South Africa.

There was a time, not so long ago, when the anthropologist doing fieldwork in South Africa concentrated upon what he regarded as the truly Native elements of Bantu culture, and attempted as far as possible to reconstruct a picture of tribal life on this basis alone. But, as we all know, Native life has altered considerably since the coming of the White man. The traditional manners and customs of the Bantu no longer survive intact, but have been modified, in varying degrees, by the combined influence of administrative action, missionary teaching, education, and above all the introduction of the European economic system. As a result, many Natives have been divorced from tribal rule and tradition, and approximate to the European in standards of living, occupation, and outlook. Others, still the great majority, retain much of their ancient culture, but are participating to an increasing extent in the new civilization. Even in the most "backward" tribal areas one generally finds European magistrates, missionaries, traders, and labour recruiters, all symptoms of the new order, and although the influence they have exercised in the direction of cultural transformation may at times have been small, it is nevertheless everywhere perceptible. There is hardly a single Native tribe at the present time which can be considered completely untouched by European civilization.

By ignoring these changes, and attempting only to compile a record of Native life as it was, or might have been, before the coming of the White man, the anthropologist went astray. His first task, the very reason for his presence in the field, is to obtain as detailed and faithful a picture as possible of tribal life as it actually exists, and any attempt to overlook the presence of the European factor cannot but result in an erroneous and distorted impression of the Native as he now is. Moreover, to the European inhabitants of South Africa the Native is more than merely an object of ethnographical curiosity. His presence has affected the structure of our whole civilization, and upon his future welfare depends the future welfare of the country. We need to know, in our own interests at least, if not in his, what is happening to him, how he is being affected by and is reacting to the civilization we have thrust upon him. The anthropologist more than anyone else should be in a position to speak with authority upon the present-day life of the Native, and he is failing

in his duty, both to his science and to his country, if he neglects the changes due to contact with the Europeans, and studies only the possibly more glamorous but nevertheless obsolescent institutions of the past.

Fortunately, anthropological aims and methods have also changed. The modern field worker in South Africa studies the life of a Native tribe as it exists at the moment of his visit, and in doing so gives due prominence to elements taken over from the Europeans. He studies the activities, influence and personality of the missionary, the Native commissioner, the trader, and the labour recruiter, just as he studies those of the chief and the magician. Where Christianity has been introduced, he investigates its organisation, doctrines, ritual, and other manifestations. just as he investigates any other form of religion found in the tribe. He treats the trading store, agricultural show, and cattle dip as features of the modern economic life, the school as part of the routine educational development of children, and the administration as part of the existing political system. He tries to ascertain how far the traditional Native institutions persist, not only in memory but also in practice; but in addition he tries to ascertain how widespread is the adoption of European elements of different kinds, what sections of the tribe have been most affected through contact with Europeans, and to what extent European practices and beliefs have become substitutes or merely additions.

Although investigations of this kind are still fairly new, there can be no question of their outstanding importance in relation to questions of Native policy. Seventeen years ago Professor Radcliffe-Brown, the first occupant of the Chair of Social Anthropology at the University of Cape Town, could write (1922: 38): "Every day the customs of the native tribes are being altered, by the action of the legislature and the administration, by the action of our economic system, through the teachings of missionaries and educators, and through contact with ourselves in innumerable ways; but we hardly have the vaguest ideas as to what will be the final results of these changes, upon the Natives and upon ourselves." To-day the position is not quite so depressing. We are at last beginning to know, on the basis not of superficial impressions but of painstaking and accurate scientific investigation, what is actually becoming of the Native in South Africa. We are acquiring a mass of concrete information telling us how far the people have succeeded in adjusting themselves to the new conditions under which they are living, whether they are contented or dissatisfied, how their health and general well-being have been affected, what they think of the various European agencies impinging upon their life, and what sort of civilisation they are tending to develop. To the Government attempting to pursue a well-defined policy of administration and development, to the missionaries preaching the message of the Gospels, to the educationist building up his schools and curricula, to the trader,

and to the employer, it is obviously essential to know just what has happened and is happening to the Native as a result of the diverse and often conflicting forms of civilisation that they bring to him. The anthropologist is now supplying this information, and the accusation formerly made against him, that his investigations were remote from the realities of present-day life, is no longer possible to-day. Moreover, it is not merely the tribal Native with whom he is concerned. The Natives working on the farms or living in the towns are also being studied intensively, so that it is already possible to make preliminary generalisations regarding the trend of Native development.

The modern anthropologist, however, goes further in his researches. He is no longer content merely to describe what he finds. He also analyses the culture as it now exists, and tries to determine why contact with the Europeans has modified Native life along certain lines, and why the Natives have reacted in certain ways to the new influences bearing upon them. He studies the history of contact between them and the Europeans, the order and manner in which different aspects of European civilisation were introduced into their lives, the policies that governed the relations of the Government, missionaries and others towards them, the influence of the personal factor in promoting or hindering the acceptance of new beliefs and institutions, and the attitude of the Natives themselves towards all these innovations. Basing his conclusions upon investigations of this kind, the anthropologist tries to explain why some Native institutions seem to have disappeared completely or lost their vitality, while others still survive, and why on the other hand some innovations were readily accepted, while others were resisted or rejected.

This inevitably leads him to examine critically the activities of the various European agencies which have influenced the life of the Natives. Here we are confronted with the question of the anthropologist's relation to matters of policy. It has sometimes been suggested, and even forcibly maintained, that it is not his business to interfere with practical issues; the missionary, the government, and the others have their particular tasks to perform, and it is not within his province to criticise their work, let alone attempt to dictate what their work should be. There seems to be some confusion here between the criticism of aims and the criticism of methods. It may be granted that the anthropologist as a scientist should concern himself solely with the facts of the situation, and not question the motives which have led to their introduction. He may have his own ideas about the advisability of evangelisation or labour recruiting, of segregation or the pass system, of abolishing *lobola* and polygamy or attempting to bolster up the chieftainship, but whether he approves or not of the ends at which they aim is a personal and not an anthropological problem.

On the other hand, the anthropologist is certainly justified in discussing the methods by which the realisation of these aims is attempted. His criticism, in fact, should be welcomed by those who have practical dealings with the Natives. The Government, the missionary, the teacher, the trader, and the labour recruiter are all trying, in some form or other, to alter the existing basis of Native life. Have the methods employed by them been successful in accomplishing the changes they desire, or have they proceeded in such a way as to produce results other than those expected? The anthropologist is often in a better position than they are to evaluate the effects of their activities, and to point out where they have gone astray, or along what lines they should have proceeded, and this he can do without questioning their motives at all.

Dr. Edwin Smith, himself one of the most distinguished African missionaries of recent times, has stated the position of the anthropologist in this respect very clearly in the Presidential Address he delivered to the Royal Anthropological Institute of Great Britain in 1934 (1934: xxv). "Just as an educationist," he says, "would not concede that anthropology had any claim to challenge his opening of schools among pre-literate peoples; and just as Government would not listen if anthropology declared that it had no right to unfurl the Union Jack over a great part of the world; so the Christian missionary could not admit that anthropology had any right to question his obligation to carry out the commission given by Christ to the Apostles—an obligation inherent in the very nature of his religion. He acts on a motive that is beyond the reach of scientific criticism; his duty is a realm over which science has no jurisdiction. But the Christian faith has vast sociological implications. The objective of the enterprise is not simply individual conversion but the creation of a community inspired by Christian ideals. The ingemination of new ideas inevitably affects the attitude of people to their traditional culture. And by virtue of their understanding of that culture anthropologists have every right to warn and advise missionaries as to the sociological effects of their teaching. That is to say, while anthropology cannot touch motive and obligation it can, and ought, to criticise missionary methods. To my mind, any missionary would be culpably foolish who should refuse to give heed to such criticism if it were founded, not upon prejudice, but upon sound knowledge. If this is understood the way is open for alliance between anthropology and Christian missionary enterprise—an alliance to be made effective by the training of missionaries in anthropology."

There are some who would go further. Like Professor Malinowski (1937: viii), they would like to see the anthropologist become the spokesman not only of the Native point of view, but also of Native interests and grievances. "It has always," he says, "appeared to me remarkable how little the trained anthropologist, with his highly-perfected technique of field-work

and his theoretical knowledge, has so far worked and fought side by side with those who are usually described as pro-Native. Was it because science makes people too cautious, and pedantry too timid? Or was it because the anthropologist, enamoured of the unspoiled primitive, lost all interest in the Native enslaved, oppressed, or detribalised? However that might be, I for one believe in the anthropologist's being not only the interpreter of the Native, but also his champion."

On the other hand, the accusation has sometimes been made by protagonists of greater liberalism in Native policy that anthropology "is an enemy of progress, because it seeks not only to record but to stereotype the past." (Smith 1934: xxxii). Dr. Brookes, indeed, actually says of what he terms the "older anthropological school, which regarded the tribal Native as the only phenomenon of study," that the most important influence it has exercised on policy has been the negative one of preventing reforms! (1934: 141). He fully realises and stresses the recent changes in anthropological methods to which I have already referred, but maintains that the older outlook is so far from dead that "to those chiefly responsible for legislation and administration it appears as the orthodox school, with the right to monopolise the term 'scientific'" (1934: 137). Professor Macmillan, again, denies that anthropology can be of any assistance at all nowadays in matters of policy. "At the present time," he says (1930: 8), "it is more urgent that we see (the Native) is provided with bread, even without butter, than to embark on the long quest 'to understand the Native mind'."

Professor Victor Murray is equally impatient of the anthropologist's pretensions, but on somewhat different grounds. "The anthropologist," he said (1938: 316), "examines Bantu handicrafts, the custom of *ukulobola*, methods of agriculture, ways of thought, the quality of *ubuntu*, and all the other characteristics of a primitive people of the present day, and he describes these things to us as 'African culture.' So far, so good, but when he goes further and declares that these things represent the 'law of the African's own being,' and that these are necessary if he is to be educated 'along his own lines,' he has forsaken the province of the anthropologist. He has ceased to deal with the present, and has laid down a rule about the future. He has become a prophet, and in so doing he has had to lay aside the authority which clothed him as an anthropologist."

With this sentiment I fully agree. It is not the task of the anthropologist to provide a solution of the Native problem, nor to advocate which of several rival policies is the one that should be followed, any more than it is his task to tell the Christian churches that ancestor-worship is more suitable for the Bantu than the New Testament, or to remind the employer of Native labour that it is "unfair" to pay very low wages. The formulation of policy must be left in the last resort to those in whose hands lies the responsibility for administering the affairs of South

Africa, and the grievances under which the Natives suffer are essentially the concern of the humanitarian and the social reformer. The anthropologist in his private capacity, as a citizen of South Africa with a better knowledge than most people of the conditions under which Natives live, may have his own views on matters of policy, and he is entitled to express them; but he must always remember, and make it clear, that in doing so he is speaking as a private citizen, and not in the name of anthropology. On this point most, if not all, of my colleagues, including Professor Malinowski himself, would probably agree. Anthropology as such is concerned with Native society as a concrete phenomenon capable of objective study; what is to become of Native society is a problem for South Africa as a whole—for the Government and the missions, the farmers and the mine-owners, the humanitarians and the Natives themselves—and not for the science of anthropology.

II.

So far I have been dealing with the anthropologist as an independent student of Native affairs. I have made it clear, I hope, that he cannot and does not claim to provide a solution of the Native problem. All that he can do is to furnish the exact information regarding Native life upon which policy must be based, no matter what other considerations are also involved, and he can further, if invited to do so, suggest along what lines action should be taken if certain results are desired. Let me now indicate somewhat more fully the manner in which I think anthropology can be employed in these two capacities in South Africa.

It has long been recognised here, as elsewhere, that a knowledge of at least certain aspects of Native life is essential in matters of administration. And, as is so often the case in this country, the usual method of obtaining the information was to appoint a special commission of inquiry. Thus, we have had, since the middle of last century, several commissions on Native laws and customs, while, since the formation of Union, similar commissions have investigated problems of Native land tenure, marriage customs, separatist churches, economic life generally, farm labour, and a variety of other topics. Although primarily concerned with administrative problems, these commissions in each case also had to ascertain the facts upon which their recommendations were to be based. They generally did so fairly competently, but it cannot be denied, I think, that they would have succeeded more fully in this respect had their personnel included one or more trained anthropologists, whose occupation, after all, it is to make investigations of this kind, and who are specially qualified to do so. By way of contrast, we may note that the Bechuanaland Protectorate Government, when it recently decided to make a compilation of Native laws and customs for the information and guidance of its officials, entrusted the task not to a miscellaneous commission, but to myself as a

professional anthropologist, and it has since employed me to study the historical development of chieftainship before and after the coming of the European administration.

In other parts of Africa, notably Nigeria, the Gold Coast, the Sudan, and Tanganyika, the administrations concerned, recognising the value of anthropological inquiry, have appointed special Government anthropologists whose full-time occupation it is to carry out investigations on those aspects of Native life falling within the sphere of administrative concern. This lead was followed by the Union Government, which in 1925 created an Ethnological Section of the Native Affairs Department, " firstly with a view to promoting scientific investigation and research into Bantu ethnology, sociology, philology, and anthropology, and secondly, in order that the Department might have at its disposal the services of an academically trained anthropologist conversant with the ethnological and linguistic side of Native affairs, accurate information in regard to which, it was realised, was likely to prove of the greatest assistance in the smooth and harmonious administration of tribal affairs and in the prevention of friction " (Rogers, 1933: 250-1). This was an extremely important and welcome step, and, judging from the fact that the section has very recently been enlarged, it has apparently been regarded as fully justified.

Nevertheless, the Ethnological Section is far too small, considering the diversity of South African Bantu peoples and the conditions under which they live, to be able to provide anything like all the information that is still required. The research work done by the anthropological departments of the Universities must, as things are, remain for a long time to come the principal source to which the Native Affairs Department and others can look for assistance. That this was appreciated by the Government itself was seen in 1926, when a sum of £1,400 annually was allocated for the promotion and conduct of researches into Native life and languages, and an Advisory Committee on African Studies, consisting mainly of representatives of the Universities, was set up to supervise the work. There was, in consequence, a rapid development of field investigations during the next few years, and a marked increase in the number of scientific publications.

In 1930, however, owing to the financial depression, the Government grant was completely withdrawn. But the Universities decided to retain the system of co-operation and co-ordination developed by the Advisory Committee, and set up an Inter-University Committee for African Studies to take its place. This Committee, which now includes among its members official representatives of the Union, the High Commission Territories, and the Southern Rhodesia Government, has done some excellent work, notably in surveying the state of our knowledge concerning Native cultures, languages, and kindred topics, planning the lines of future research, and publishing standard works for students and others on ethnography and linguistics. But it has been

greatly handicapped by lack of funds. Through the agency of the International Institute of African Languages and Cultures in London, grants for research were for a while made available to a few South African anthropologists, but this source too has now failed. The Research Grant Board of the Union has also helped to finance some investigations, but it cannot do so to anything like the extent that is desirable. Appeals to the Government for renewed assistance have been consistently rejected, on the ground that the Universities should out of their ordinary funds make provision for anthropological research. It can only be regarded as a pity that a Government which annually spends some £3,300 on maintaining a Bureau of Archæology should not find it possible or advisable to make similar provision for what is, after all, the far more important and urgent task of collecting information about people who constitute a living administrative problem, and are not, as yet, merely dead relics of South Africa's ancient past.

In this connexion the words of the Native Economic Commission are of direct relevance. After discussing the policy to be adopted in administering and developing the Native Reserves, the Commission says (1932, § 249): "If the method of dealing with Natives in the Reserves which your Commission has outlined in the foregoing paragraphs is adopted, it will be necessary to devote more attention to the scientific study of the Natives than has hitherto taken place. The Universities have for some time devoted their attention to this subject, and a good deal of investigation has taken place by private research. Your Commission considers that greater encouragement should be given to such work, and that steps should be taken to facilitate co-operation between officials dealing with Natives and scientific investigators, to enable the results of such work to be used to assist in dealing with administrative questions dependent on a knowledge of Native customs."

It is not only the Governments which have seen the advantage of employing trained anthropologists to make investigations on their behalf. Several years ago the Tea Expansion Bureau, a world-wide organisation, employed several anthropologists in South Africa to inquire into the tea-drinking habits of the Natives, with a view to exploring the possibilities of extending the local market for tea. More recently, the Johannesburg Municipality has attached to the staff of its Native Affairs Department a permanent anthropological research worker to study the social life of Natives dwelling on the Rand and the transformations through which it is passing. These are welcome indications that the importance of anthropological research is gaining increased recognition.

There are many other directions in which the assistance of an anthropologist would be of value. Lord Hailey in his "An African Survey" (1938: 58-59), lists malnutrition, agricultural improvement, the collection of vital statistics, the problem of soil erosion, and the effects of labour migration, as among the

topics for investigation requiring the co-operation of the anthropologist. The Mission Churches, again, faced with the rapid growth of Native separatist churches, would find it extremely useful to add an anthropologist to the body of inquiry which they are planning to set up to deal with the problem. It would also benefit them greatly to foster similar inquiries into the beliefs and practices of Native Christians, which sometimes assume forms differing widely from what is taught in church, and into the effects produced by the abolition of polygamy, *lobola*, and various other customs generally regarded by them as incompatible with the principles of Christianity. One such inquiry, I understand, is actually under way, into the different forms of marriage prevailing to-day among the Natives.

The anthropologist, however, need not only be an investigator. He can also be useful in an advisory capacity. Without himself being committed to any particular line of policy, he can show from his knowledge of Native life what the probable effects would be of certain measures, or, if certain results are desired, what the most suitable methods of achieving them would be. As Mr. Driberg says (1927: 157), perhaps more confidently than I might have done myself: "Anthropology does not and cannot decide pragmatically on the respective merits of, for example, direct and indirect rule or the policy of Native reserves: what anthropology does is to demonstrate that applied to this or that culture direct rule would be followed by certain results and indirect rule by other equally definite results; that segregation in Native reserves must have some inevitable sociological or biological consequences; and so on." This does not mean that the advice of the anthropologist need necessarily be accepted. Considerations of policy may demand that a certain line of policy should be followed, whatever the results; but at least, by seeking the advice of the anthropologist, the authority concerned, whether administrative, religious, economic or educational, will be able to visualise more clearly what the consequences of its actions are likely to be.

Here again South Africa provides a few illustrations in which this fact has been appreciated. Several years ago the Swaziland Administration consulted various anthropologists, among others, on the possibility of adapting the traditional military organisation of the Swazi to modern educational needs and methods. The Bechuanaland Protectorate Administration has for some time now had a professional anthropologist on its Board of Advice on African Education. Very recently, again, the Administrations of the Union, South-West Africa, and Bechuanaland Protectorate, in setting up a Joint Standing Committee on the Bushman problem, included an anthropologist as one of the members. This system of consultation could be extended in many other directions, especially in the Union, where under the present Native policy a comprehensive scheme of development is being planned for the Native reserves. It is surely not being too bold, for instance, to suggest that the Native Affairs Commission would

stand to gain considerably if one of its members were a trained anthropologist, or that future Government Commissions on Native questions should include anthropologists as well as other technical experts.

III.

There is one other field in which anthropology may claim much more recognition than it has so far received in South Africa, and that is in the training of persons who intend to work among the Natives. A large number of Europeans are engaged, as officers of the Native Affairs Department, as missionaries, as teachers, and in other capacities, in occupations bringing them into intimate daily contact with the Natives. It does not need to be emphasised that a knowledge of Native life and languages would be of the utmost value to them in their different spheres of activity. As Dr. Edwin Smith has said, with particular reference to administration (1934: xviii-xix): " It makes all the difference when a man has, and the people know he has, an informed sympathy with them, talks with their mother-tongue, appreciates and practises their code of etiquette, understands their laws and customs, can follow the workings of their mind. The best administrators have always been those who are most able to see the world through the eyes of the people over whom they are placed." And the Chiefs of Bechuanaland Protectorate, when on their famous visit to England in 1895, implored Mr. Joseph Chamberlain to give them as Resident " a good man who knows our speech and customs, and is not bad-tempered and impatient, one who loves us " (Blue-Book C. 7962, 1896: 14).

This point has been so repeatedly made during recent years that it need not once again be elaborated. It is far more instructive to see what has actually been done about it in practice. All candidates for the British Colonial Service, which now includes the three Native Protectorates of South Africa, must, after selection for appointment, spend an academic year at either Oxford or Cambridge. Here they receive a special course of instruction which includes, among other subjects, lectures on general and regional anthropology, and in the language of the territory to which they are assigned. Selected candidates for the French Colonial Service spend two years at the Ecole Coloniale, and here again anthropology and Native languages are among the subjects studied. In Belgium there is a similar course extending over four years, in each of which anthropology and Native languages are taught; while in Holland candidates for the Colonial Service undergo a five years' course of instruction. Many overseas Mission societies, too, have now arranged that their missionaries should receive some training in these subjects before proceeding to the field.

In South Africa the position is very different. In Southern Rhodesia officers of the Native Affairs Department are appointed for a probationary period in the first instance, during which they

must pass special examinations in Native languages and law, and during the past few years facilities have from time to time been given for study leave to be spent at some University teaching these subjects. Very recently, again, the Native Affairs Department of the Johannesburg Municipality requested the University of the Witwatersrand to institute a two years' diploma course in Native administration to be taken by candidates for service in the department.

But the Union Government itself has lagged far behind even Southern Rhodesia and the Johannesburg Municipality. The situation as it exists here is well summarised in a memorandum recently drawn up by the Inter-University Committee for African Studies, in which renewed proposals are made for the training of candidates for the Native administrative service: " The training in Bantu Studies and kindred subjects offered at the Universities," says the memorandum, " is not recognised as any form of qualification for entry to administrative services which deal chiefly with Native affairs, nor does the student who qualifies in such subjects obtain any seniority or monetary advantage. The £50 bonus formerly given to members of the Service who took the Diploma in Bantu Studies has now been withdrawn, and no provision is made for members of the Service to attend courses in Bantu Studies at any subsequent period of their career, as is the practice in a number of British Colonial Services and those of Belgium and France. The Native Affairs Department has recently agreed to give five years' seniority to students who have taken their LL.B. degree, plus one year of Native law, anthropology, and a Native language, but such a long training does not qualify the holder to pass into the first grade of the Service, and the provision naturally only applies to a very small number of entries to the Native Affairs Department. Thus, any University student who desires to specialise in subjects likely to fit him for service as highly specialised as Native administration has little advantage over those who enter the Service with Matriculation Certificates only, in fact he is penalised for the qualifications he has obtained since he loses three years' seniority by taking this training."

" In view of these facts," the memorandum continues, " it is not surprising that students applying to the Bantu Studies Departments of the Universities often announce their desire to enter the Native Affairs Department of the British Colonial Service and not that of South Africa, although territories like the Union and Southern Rhodesia should be able to attract the pick of the young men of this country, rather than the less healthy areas such as Nigeria and the Sudan, in which it is impossible for a man to bring up his children or settle permanently."

" South Africa," the memorandum adds, " is in fact the only Government administering so-called 'Native territories' which does not recruit or train specially qualified administrative officers for the task, either by selecting its candidates for the

higher grades of the Service by means of a competitive examination from among students already possessing University degrees, or by establishing a special institute for training students in Colonial administration, and which does not provide facilities for further training for officers already in the Service by means of special courses for which extra leave is given."

The position, as revealed by these quotations, is most disappointing and disquieting. Officers of the Native Affairs Department must speak the two official languages of the country, and pass the Civil Service Law Examinations; but they are apparently not required either to speak the languages of the peoples with which they are most directly concerned, nor is any special knowledge demanded from them of the Native laws and customs which they have to administer. There have actually been, and still are, officers of the Department who can be considered experts in both Native law and Native languages, and there are many others studying in their spare time to acquire a similar proficiency. But there is no official insistence upon this, nor any obvious encouragement. A training in Native law, anthropology, and Native languages will not of course in itself make a man into a perfect administrative officer, but it will at least render him more efficient, and should therefore be an essential requisite for admission into the Service. The Native Economic Commission has emphasised the desirability for some such system of training, especially in regard to Native languages. "It will be evident from the general tenor of this Report," it says (1932, § 243), "that your Commission lays great stress on basing all action in regard to the Natives on an intimate knowledge of these people, of their languages, their mode of thought, their manners, and particularly of their social and economic systems. It was made abundantly clear to us how frequently misunderstandings arose and ill-feeling was generated owing to a lack of comprehension of these factors. We wish also to stress the need for Government officials being able to speak the local Natives' own languages. The general advantage to the State, in many ways, of a knowledge of the vernacular on the part of European officials, and police, is self-evident."

In view of this explicit statement, and of what has been done elsewhere, I need not discuss more fully the case for the training of our administrative officials. It is somewhat ironic that in a country where at least six Universities and University Colleges have Departments of Bantu Studies, none of these Departments is actively engaged in preparing candidates for acceptance by the Native Affairs Department, although several young South Africans who have made a special study of Native life and languages have found their qualifications a decided asset for admission into the Rhodesian and British Colonial Services. Among the students who have passed through the School of African Studies at the University of Cape Town, there are some in the administrations of Southern Rhodesia, Bechuanaland Protectorate, Tanganyika

and even Nigeria, but none, so far as I know, in the Union Native Affairs Department. Here, it would seem, is one field at least in which science has failed to reach the people by whom it could most usefully be employed; and if this Association would join with the Universities in their effort to produce a change that cannot but benefit Native administration in South Africa, and with it Native affairs as a whole, I shall feel that my address to you to-day will have achieved something of value.

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CRIME AND ITS PUNISHMENT

BY

THE HON. F. E. T. KRAUSE.

Presidential Address to Section F, delivered 5 July, 1939.

The object of science is to increase our knowledge and to arrive at the underlying principles of existence for the guidance and benefit of man. It is truth that we are seeking. In the natural sciences the laws of nature are ascertained by observation and experiment, and so we are able to arrive at definite and accurate results. When we, however, come to the study of man, especially in his relation to his fellow man in society, we find ourselves dealing with a very complex problem, as the differences between human beings, even living in the same community, as regards temperament, character, individuality and generally in mental outlook, are indeed marked. These differences, however, on closer study, are explicable and we are able to arrive at fundamental principles which clearly point to the fact that human nature is essentially very much the same all the world over and that the variations which do exist are largely due to climate, race, religious outlook and other factors. In dealing with crime we have to study man in his relation to society. The human being is a gregarious animal. From the earliest times men have combined to protect themselves not only against wild animals, but also against other hostile communities. To enjoy the privileges of protection, the individual had to subordinate many of his rights to those of the community. Freedom is but relative. I once, over the radio, heard a well-known politician say, that "The State was made for man and not man for the State." He intended this "slogan" to be an argument in favour of our present-day democracy as opposed to other systems of government. As a fact, man made and evolved the State for his own protection and entrusted the State with the duty of safeguarding his interests and rights. It is a fallacy to maintain that a citizen can say and do as he likes under any form of government. To ascertain to what extent the liberty of the subject is curtailed in each system of government, one should study the laws in the different countries and then one will find, that the restrictive laws differ only in degree and that despotic or arbitrary rule exists in every civilised country under every system of government. Lord Hewart, the lord Chief Justice of England, in his book "The New Despotism," draws attention to the alarming fact, that in our so-called democratic or parliamentary State, we are not ruled by laws made by Parliament, but principally by regulations framed by bureaucratic officers, and that even the courts cannot come

to the assistance of the harassed citizen. The statement that our Democracy is being attacked and must be defended is a fit subject for impassioned oratory, and is in fact mere political camouflage. The danger does not come from without, but from within. Our universal suffrage leads to rule by the "howling mob" as "A gentleman with a duster" rightly remarks. When the party whip cracks, then the team falls into line and the rewards of office or other advantages generally keep the gibbers in their place. If you should dare honestly to differ from the policy of the Government in power and express progressive and liberal views, then you are exposed to censure by the causus, as has just happened to two able members of Parliament.

Recently in a London constituency 30 per cent. of the electors went to the poll—so one may take it that the fortunate candidate was returned by at most 16 per cent. of the voters. The methods which must have been employed to induce them to vote for the party politician may be left to the imagination!

With the growth of industry and the general progress of social activities, so many laws, rules, regulations and by-laws have been made that the ordinary citizen is at a loss to know really what modicum of freedom he still enjoys. It would appear that his life and property are his own only when the State does not require them, often for some plausible reason advanced by politicians or by those who for the time being happen to wield the supreme power in the State Now, in every well-ordered community there will be found citizens, who for some reason or other are or become anti-social. Broadly speaking "Crime" is conduct which violates those laws, which have been made to secure the utmost freedom for each individual citizen compatible with the common rights of other members of the community. Violation of these laws is visited by the State with what is termed "punishment."

Historically crimes have been divided into *mala in se* and *mala prohibita*. By the former is meant such evils as have been universally accepted by the human race as being evils in themselves—e.g. murder, robbery, theft, assault and so on, and by the latter is understood those evils which the community from time to time has considered it necessary and expedient to prohibit as being contrary to the common good. There is no great difficulty in ascertaining the rule of law which constitutes a "crime." In many countries comprehensive penal codes have been promulgated and in others, where law is still partly regulated by custom, the Courts have clearly defined which laws are and which are not of a penal character. It is a well-recognised principle that no citizen should be liable to prosecution unless it is incontestibly established that there is a law which makes his conduct criminal. "*Nulla poena sine lege poenali.*" If it should happen that, due to an omission or forgetfulness on the part of the legislature, certain conduct, compared to other conduct which is prohibited, is equally detrimental to the interests of the community and

should also have been, but has, in fact, not been prohibited, then no prosecution can be instituted against anyone who is guilty thereof. The citizen is entitled to know what he may or may not do, and to punish him for what he was not told not to do, would be unjust and an exercise of arbitrary power. The number of our penal laws has, during the last fifty years, increased immensely and consequently the appropriate punishment which should be inflicted for violations, has become a problem of great difficulty and complexity. Unfortunately we are intellectually often confirmed parasites—and I regret to say that lawyers are reputed to be the worst ones—we live on the thoughts of past generations and try to perpetuate what has gone before without reference to the progress science has made and without taking into consideration the altered conditions of life. What was good enough for my ancestors is good enough for me! That is the slogan. It is a mental obstinacy which in certain instances amounts to fanaticism. That old patriarch, Paul Kruger, admonished his people to study the past, but only to retain that which was good. Conservatism, within limits, may be sound policy and reflect great wisdom, but blind idolatry of the past is indefensible and may be pernicious.

Now, there is no matter, affecting the welfare of the community, where there has been greater conservatism and an obstinate disregard of the truths of science, than the subject of crime and the appropriate punishment for the wrongdoer. In the past, to be called a " criminal " meant, that the individual was outside the ken of decent people. With unctious rectitude people turned the cold shoulder on those who had come into conflict with the criminal laws and refused to lift a finger to assist them, even though they had paid the penalty for their wrongdoing. Now, the criminal is not born, but is the product, in the majority of cases, of our social and economic conditions. He is one of us—just the ordinary citizen—and it is often pure accident, or perhaps just good luck, that many of us do not find ourselves in the same category. Having regard to the innumerable regulations and by-laws that we have to obey, I feel convinced, that many of us have at one time or other for some contravention or other earned the generic appellation of " criminal." I wish to make it perfectly clear that, in dealing with the question of punishment, one should discard all maudlin sentiment and face the hard facts of life. It is not the intention of those who have given this matter serious thought and who have come to recognise the truths that the progress of mental and social science have revealed, to advocate a home of luxury for those who have proved to have been anti-social in their conduct. Again, antiquated ideas must be abandoned, and uncivilised and barbarous methods of treatment of the wrongdoer must be discontinued.

In ancient times the underlying principle of punishment was revenge and compensation to the injured person or his family. " An eye for an eye and a tooth for a tooth," was the biblical

conception of the object of punishment. When the Headman or Prince or King, and subsequently the State became the avenger, a system grew up whereby definite forms of punishment were prescribed for particular crimes. The principle of revenge still largely dominates our criminal jurisprudence and there is a large number of educated and presumably civilised people who would be shocked if the punishment imposed were not proportionate to the injury inflicted by the wrongdoer, or to the heinousness of the crime—this is especially so where violence is one of the elements of the crime. Many persons again are quite incapable of expressing their just indignation at some revolting offence except by advocating the most barbarous and inhuman treatment. You will remember that some time ago the Press made quite a feature of the discovery of the prevalence of so-called moral or sexual aberrations, and judicial officers, in dealing with the delinquents, gave expression to such exaggerated views as: "If I had the power to do so I would have you lashed." "You are a corruptor of our youth and deserve to be whipped." "Should any case of an assault on a white woman by a native come before me, I shall have no hesitation in having the culprit hanged"—and so on. I could multiply these crude expressions of opinion. Those who have but a superficial knowledge of human nature and of the world as it is, know that these acts of immorality and indecency are as old as the hills. They date from the very dawn of the human race I remember in a certain case a large body of influential and presumably christian women presented a petition to the Minister of Justice to pass a law providing for the emasculation of any native who should be found guilty of any sexual assault on a European woman or girl. Science is constantly reminding us that sexual excesses are part of the human make-up and that pathological treatment would in most cases be more effective than barbarous treatment, which often exhibits pronounced sadistic tendencies in the very person advocating such methods. Surely the time has arrived when the lessons of science should have taught us that our false sense of prudery must be corrected, and that the reasonable way to deal with sexual deviates is to recognise the fact, that sex is the basis of all human, animal and other life, and consequently that pathological factors lie at the root of the problem. The imposition of imprisonment, especially lashes, for such aberrations, reveals a deplorable ignorance of the physical make-up of man. Such persons should be sent to, and be treated in, certified institutions. To send them to prison and to lash them is the greatest disservice one can do to society.

In my opinion the pricipal object of punishment is, and should be, the protection of the community from the anti-social conduct of some of its members. The methods to be adopted to attain that object should be based upon the knowledge which science has revealed, having regard to the hard facts of human existence. We often hear it stated, that the punishment

inflicted acts as a deterrent to others not to do likewise. It is also preached, that the wrongdoer should physically be made to feel the hurt that he has caused his victim. The least serious contemplation of the matter and but a cursory examination of known and proved facts will demonstrate, even to the most obtuse mind, that the so-called deterrent effect of brutal and vicious punishment is practically negligible. Hanging, even public hanging, has not prevented nor decreased the number of murders, and careful investigation of cases of violence has shown that flogging has in no way diminished the prevalence of such offences, in fact in Scotland, where flogging has been abolished for many years, such cases have actually become less frequent. Subjectively, however, many persons still believe in the deterrent effect of severe and cruel punishments, but I am so bold as to challenge such persons to demonstrate by reliable statistics or other satisfactory proof the truth of their subjective opinions.

In the past, and even at the present time, it was and is the accepted doctrine, that the nature of the "crime" should dictate the punishment, whereas science and experience have shown that punishment should be regulated to suit the "criminal" rather than the crime. This is only common sense.

Protection of society from its anti-social members is one of the main functions of government. As the harm to the State comes from its ordinary citizens, the first approach to a scientific solution of the problem is the study of man himself. The progress which mental science has made during the last 20 years has been phenomenal. The causes of human behaviour have been carefully analysed—the operation of the conscious and the sub-conscious mind on human behaviour has been clearly demonstrated and generally speaking our knowledge of human nature has been enriched to such an extent that definite principles or rules have been revealed.

I was impressed by an article on "The Hysteroid Personability," in the April issue of "Scientific American" by Dr. Paul Popenoe. In speaking of "human personality," he says that there are two contrasting types. The paranoid personality, who is always on the aggressive. He is not merely ready to meet trouble when it comes: he is looking for it, and is prone to imagine it where it does not really exist. His whole life tends to become a fight. The hysteroid personality again is always on the defensive. He is always trying to escape, not merely from real, but from imaginary, dangers. His whole life tends to become an evasion, a sham, a pose. He says, there is a difference in the complexity, in the diversification, of the two types of personality, which reflects the differences in nature, and though contrasted, the two types are not mutually exclusive; all of us have some tendency in each direction. It is only in pronounced cases, where the balance is greatly on one side, that one speaks of the paranoid or the hysteroid personality. Most of us are betwixt and between.

Politicians tend to fall into two separate groups. One is made up of the paranoids—aggressive, domineering, driving ahead ruthlessly, crushing opposition relentlessly; stubborn, suspicious, belligerent—a type, the Doctor says, illustrated by some political bosses in America—and by such well-known figures as George Clemenceau and Thaddeus Stevens. The other group is made up of the hysteroid type—posers, gifted with imagination and continually dramatising themselves before the public. Their natural bearing is that of "pose." This type blossoms most exuberantly among the "big shot" frauds and swindlers, the bluffers and confidence men who get even more satisfaction from strutting across the stage and "putting one over" on the public, than from their actual gains. As examples of this group he mentions Joseph Balsanco, who called himself Count Cagliostro, John Law of the Mississippi Bubble, and Horatio Bottomley. He says that if the extreme hysteroid has a different type of constitution from the average person, then both prevention and cure will be difficult. "Spoiled child" tendencies appear early and are largely fixed during adolescence—consequently an education that prevents the development of a "spoiled child" will prevent the development of a hysteroid. In dealing with an adult, one should make him see not only "why" he is sick, but also try to give him a "desire to be well." If the cause can be removed then the whole career will be changed. According to his view it would be optimistic to think that much can be done with an inferior, infantile, disintegrated adult who is making use, to his own satisfaction, of such primitive biological mechanisms as are the basis of the hysteroid personality.

I have advisedly quoted freely from Dr. Popenoe's article, because the results of his scientific inquiries are a valuable contribution to an understanding of the problem which confronts us.

Our first study must be human personality and when once we have analysed and appreciated its complexities, then only will we be in a position to investigate and lay bare the fundamental causes which go to produce anti-social behaviour.

Lord Samuel, in a lecture delivered in October, 1938, entitled: "Is the criminal to be blamed—or society," made some pertinent remarks as to the causes of crime, which are worth quoting. He said:—

> "The lesson that society should have learnt very early —but it has proved to be one of the latest—is that individuals differ, and that we ought not to treat them all alike, under a standard tariff of punishments apportioned merely to the character of the crime. It has taken a long time to get away from that crude and cruel rule. We realise now that we must study the offender first before deciding how to deal with him. Not every patient needs a dose from the same bottle.
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> "Three factors combine to cause criminal actions, as indeed any actions of any kind. The first is the physical

nature of the person who acts; this is primarily the product of heredity, but is affected by environment and by the habits that he has himself formed. The second is the complex of influences continuously brought to bear upon him by society, in infancy, childhood, youth and adult life. The third is his own power of choice: in a particular case he may not exert himself, and may passively, as it were, follow the line traced by his past; but on the other hand he may, by an effort, apply his will and exercise his judgment and with full consciousness choose his course.

"Since there are those three causal factors—heredity, environment and individual choice, our remedial measures must have regard to each of the three. Heredity is the province of eugenics. We have to consider what steps are possible—so far as any are possible—to encourage breeding from good types rather than from bad types. But this is a specialised subject, which requires separate and expert examination. It is not for me to enter into it here.

"Environment raises questions of a more general character, and is more amenable to social action. It is not less important than heredity. For after all, a man's future is not pre-destined from birth; he is not born a saint or born a gangster. There is pre-disposition, true; but not pre-destination. Crime, like alcoholism, or phthisis, or many other things, is not an inescapable inheritance; but a tendency to it may be inherited; a man's family history may be such that it would be well for him to be on the watch.

"Education is society's best instrument. Other things being equal, a well-educated nation will be at a higher level of civilisation than an un-educated nation, and will have a lower percentage of crime.

"Housing conditions are another part of social environment which is important in this connection. Slums breed a degraded population, and keep it degraded. In dark and dirty corners the anti-social germs lodge and multiply. The best disinfectant is fresh air. Well-planned, wholesome towns and cities will be less likely to foster centres of crime, as of disease.

"The economic factor counts for even more. Poverty is, without question, the chief cause of crime. More than from any other one cause, people become criminals because they are pressed by need and yield to temptation.

"But even if the social system were perfected, even if everyone in the land were well-educated, well housed, well-paid, regularly employed—would crime disappear altogether? We can hardly believe it. That offenders would be reduced to a fraction of their present number might be confidently expected; that they would cease to exist would be too much to hope. There would still be crimes of passion, sexual perversions, temptations to fraud.

"Until quite recent years the courts sent wrong-doers wholesale to prisons and reformatories. Only after they got there was any attempt made to study their characters, to find out the facts behind the offence, and to consider what kind of action would really be best for them. The rule was treatment first, diagnosis afterwards.

"Some offenders prove intractable, do what we will. In the last resort it is they themselves, and not we, who must decide whether they will be law-abiding or not. If they finally decide not to be, society must have some recourse for safeguarding the life and property and peace of orderly citizens. In the world as we have it unilateral disarmament unfortunately is not the path of safety. I am glad to note that the Departmental Committee on corporal punishment, consisting of ten able and impartial men and women, has recommended, after hearing much evidence and long and painstaking inquiry—unanimously—that judicial sentences of birching and flogging, whether for boys or for men, do not serve the purpose in view, and should be abolished for all offences. That form of penalty has been abolished in every civilised country in the world, except in the British Empire and in a few among the United States of America, and I trust it will not be long before it is abolished here also.

"My answer to the question, 'Is the criminal to blame —or society'? would be—sometimes one and sometimes the other, but usually both."

I so thoroughly agree with the views expressed, that I make no apology for reproducing them for the benefit of those who may not have had an opportunity of reading them.

Other causes, fruitful in the creation of criminals is "war" and the fostering of "war mentality" which is so assiduously being done by certain persons at the present time for purposes of their own. Crime follows and is the obvious result of war. The loss of social self control, both in government, in business and in industry, is fed by war. Increase in open crime is the easiest and simplest phase of the post-war epoch. The Great War, in common with every war, gave the men in service contact with demoralising patterns of behaviour, and increased the failure of the family to function as a social educator, thus directing the race into channels of criminal activity. The everyday work of the soldier consisted in performing the very deeds, including the killing of his fellow human beings, which, under every civilised code, constitute the major crimes.

Dr. Lorentz in an article appearing in "Mental Hygiene" in 1923 says, that in 1922 it was estimated that approximately 20,000 ex-servicemen were in penal institutions throughout the United States. Exner in his book "Krieg und Kriminaliteit in Oesterreich" (1927) states, that in Austria before the war there were 209·5 sentences for crime for every 100,000; whereas after the

war (1920) there were 586·6 for every 100,000. Even the countries which were neutral, but who suffered under the economic warfare carried on in Europe, exhibited a war criminality which was akin to that of the Central Powers, even although they did not actually participate in the war—namely Sweden, Norway, Holland and Switzerland.

When one considers that among the great world powers for four and a half years the acts which constitute the major crimes were the purpose of life, one can readily understand this increase in criminality.

Liepman, in his book " Krieg und Kriminalität in Deutschland " (1930) points out, that in Germany exactly the same has happened as in other countries. He says that the "high point of war criminality for young people lies in the year 1918." In that year 99,493 young persons were sentenced for crimes, being more than twice the number of 1914, and that the increase of murders committed by women toward the end of the war was about three times as great as in the previous years.

The " fostering of a war mentality " in the public whereby demoralising patterns of behaviour are preached and hatred and suspicion are sowed, must eventually break down those stabilising moral influences which are the mainstay of civilised and ordered life and so lead to crime. Certain individuals, for political, financial, and other reasons, have started and are continuing to encourage hostile and false propaganda, with a view to creating a definite war mentality in the masses and an unsettling influence in industry and commerce. Unfortunately it is the abuse of the press that has enabled them to do so. In our modern world (whatever may have been the position of the press in past years) there is no such thing as a free press. It is mere camouflage, calculated to deceive the public, to say that there is a free press. The running of a newspaper is essentially a commercial undertaking and the policy of the paper is effectively controlled by its owners. There is no desire on the part of anyone to create a censorship of the press, but a law should be made to prevent its abuse. A careful check of foreign (especially continental) political news has shown that approximately ninety per cent. of such news is hostile and either doctored or deliberately false. You will have observed instances of cases reported in daily publications, with harrowing and often distressing details of treatment meted out to individuals overseas, to find the whole story contradicted in later editions as being without foundation. The danger is, that those who read the first account may never read, or even hear, of the subsequent contradiction or correction. The press is a great power for good or for evil. There is no reason why the person or persons, who are responsible for, or connive at, or assist in, the publication of false news, whereby the public is deliberately deceived or is induced to act to the detriment of its peace of mind and property, should not be amenable to the law. The type of person or persons, who are responsible for

this abuse of the press are not the ordinary anti-social citizens and an effective way to deal with them is through their pockets, especially by prohibiting the publication of the paper in question for a definite or even indefinite period. There is no greater menace to the peace of the world than hostile and political propaganda through abuse of the press whereby falsehoods are spread about other nations. Unfortunately Government departments are often the chief culprits. A newspaper is not only a commercial, but also a " private " undertaking, and there is no valid reason why an appeal should be made to the " public " to support the malpractices that I have mentioned, on the plea, or under the cloak as if a " public " undertaking is going to be subjected to unnecessary hardship or interference, or that the liberty of the press is being menaced. Freedom of criticism is welcomed, but when it is based on untrue facts, then it is merely a repetition of the falsehood in an altered form. It is the duty of the State to protect the nation against these " warmongers."

Having dealt with crime in general and its causes, the difficult question of how to deal with anti-social conduct of the citizen calls for consideration. Logically, if one were to eliminate the causes of crime before anti-social conduct manifests itself, then no further problem would be left. If you improve the economic conditions of the people, if you uplift them intellectually, if you maintain peace and guarantee security, if you prevent demoralising influences affecting the minds of people, then the reasons for anti-social behaviour would, if not entirely, then at least substantially, diminish. Prevention of crime, especially juvenile delinquency, is a matter which intimately concerns social welfare and other societies and is one of the important duties of probation officers. The work done in this connection has been phenomenal and the results achieved have been most encouraging—one's appreciation goes out to those self-sacrificing and understanding persons who have undertaken this onerous task.

The number of probation officers in the Union should be largely increased, our social service organisations should be adequately subsidised and all such bodies and persons who are chiefly concerned with the prevention of crime, especially in so far as it affects juvenile delinquency, should be supported and encouraged to continue the good work. The solution of the problem also of the after care of the discharged prisoner, should be left in these capable hands. It is the duty, however, of the State financially and in every other way to support this work.

The State must, however, step in when a crime has been committed and brought home to an individual citizen. Punishment then follows as a matter of course. The courts are entrusted with the duty of sentencing the accused and inflicting one of the specified punishments which the law prescribes. Its nature and the manner in which the accused, after sentence, should be dealt with, are problems which, until recently, have received but scant consideration at the hands of law-makers.

The courts were, and are, bound to apply the law as it exists, and little, and often no, discretion at all is left to the officer presiding as to the punishment he may inflict. Gradually there has developed a " rule of thumb " method in our Courts and the nature of the crime, usually, indicates the punishment, which in the circumstances is imposed. Even the ordinary layman could with some certainty foretell what punishment one might expect for any particular crime, in other words, the close relationship between crimes and punishments conform to schedule, and surprise is expressed when a Court happens to depart in any particular case from the accepted and customary schedule.

In South Africa Section 338 (and following) of the Criminal Procedure and Evidence (Amended) Act, 1917, deals with the nature of punishments. The sentences which may be passed are (1) death by hanging for murder, treason and rape; (2) (a) imprisonment with or without hard labour, with or without solitary confinement and spare diet; (b) declaration as an habitual criminal; (c) fine; (d) detention at a farm colony; (e) detention at an inebriate reformatory; (f) detention at a juvenile or juvenile adult reformatory with apprenticeship thereafter; (g) whipping; (h) putting the accused under recognisance with conditions.

Previously the death sentence was compulsory for murder, but now by Section 61 of the General Law Amendment Act, 1935, the Court may impose any other sentence where the jury have expressed the opinion that there are extenuating circumstances.

The Prisons and Reformatory Act, 1911 (amended) deals with the carrying out of sentences. Reformatories have now been placed under the jurisdiction of the Education Department. This has been the first tangible proof of a change in the policy which regarded the " crime " and not the " criminal " as the principal factor in awarding punishment.

When one turns to the Prisons Act and the regulations framed thereunder, one cannot help feeling that the whole conception of the manner of carrying out the sentences imposed breathes a spirit of brutality and savagery. Let me elucidate. According to Section 352 of the Procedure Act the number of strokes that a superior court may impose may not exceed fifteen unless some Statute allows a larger number. A magistrate has the same power.

A prisoner who escapes or attempts to do so is liable on conviction by a court of Resident Magistrate to imprisonment with or without hard labour for a period not exceeding two years (the ordinary jurisdiction of the magistrate is six months), and in addition, when the escape or attempt was accompanied by any act of violence, to corporal punishment not exceeding 24 strokes. A convict or prisoner who has displayed, or is threatening violence, or who has been recaptured after escape, or who, there is good reason to believe, is meditating escape may be ordered by a superintendent, assistant superintendent or gaoler, as often and

as long as it is urgently and absolutely necessary, to secure or restrain such person, to be confined in an isolation cell, and in addition, or in the alternative, may be placed in irons (the weight not to exceed ten pounds) (reg. 439), or be subjected to some other means of mechanical restraint for a period not exceeding one month (Section 25 of the Prisons Act). The prison regulations provide, that for contravention of any disciplinary rule the superintendent or assistant superintendent may impose corporal punishment not exceeding six strokes—a visiting magistrate again may impose strokes not exceeding twelve.

According to the best informed medical opinion the number of lashes which a human being is capable of enduring varies from five to 10. Thereafter you are just hacking dead human flesh—the nerve centres become completely paralysed. The skill of the operator is, of course, an important factor.

Other alternative punishments are provided, e.g. deprivation of one or more meals, solitary confinement with or without spare diet for a period of from six days to 42 days (reg. 421). A prisoner must (reg. 420 (25)), in speaking to an officer stand at two paces distance and must not breathe into an officer's face to make him hear; he must (reg. 420 (32)), on entering the dining hall, take his seat promptly, position erect, with eyes to the front and not commence eating until the signal is given; he must (reg. 420 (33)) observe strict silence during the meal, must not stare at visitors, must not laugh, fool or gaze about the room; must (reg. 420 (38)), after finishing his meal, sit erect until the signal is given to rise, then march out in line in a prompt, quiet and orderly manner; must (reg. 420 (41)), in talking to his officer, confine himself strictly to the work in hand.

When the Prisons and Reformatories Act was passed and the regulations thereunder made (twenty-eight years ago, in 1911), the doctrine of retribution and revenge was and is still now the underlying principle of our penal laws. The great advance of mental science and of sociological research since then, have been almost entirely ignored or shamefully neglected by those whose duty it was to keep in touch with, and give effect to, the progress of our civilisation. It was not, and is not now, the prescribed function or duty of the prison staff to do anything towards the *actual reform* of the prisoner. It is the duty of officers to see that convicts in their charge work steadily throughout the day and without idling or talking (reg. 218), and they must at all times watch the various movements and employments of the convicts (reg. 220 (1)) and promote industry, maintain order and prevent escapes. They must also (reg. 220 (2)) carefully observe the character, habits and industries of the convicts (but this is merely for the purpose of complying with the system of marks which a convict can earn in order to entitle him to remission of sentence for good conduct). A convict or prisoner must therefore be constantly kept at work—according to the accepted doctrine. The regulations (80, 268 and 269) provide, that the superinten-

dent and chief warder shall see that all sentences for the punishment of convicts are duly carried out, that the convicts for whom exercise is prescribed, are exercised daily, and that they are not allowed to sit or loiter about the exercise yards, but are kept occupied at all times.

The rules which convicts have to observe while undergoing sentence are bewildering (reg. 420). There are no less than 55 of them. There are 30 specified offences that might be committed against prison discipline (reg. 421). An analysis of these regulations forces one to the conclusion, that they reduce the prisoner to a mere number and that militarism, which usually disregards all humane considerations and peculiarities of the individual, dictated them. They are the result of the traditional conception, that the object of punishment is to make the delinquent feel, through physical pain and degradation that he is an outcast of society. This is substantially the doctrine which underlies the policy which our legislature has adopted. It is based upon the traditional and antiquated conceptions, handed down to us from the middle ages, when leg-irons, the rack, lashings, thumb-screws and foul dungeons were the punishments considered to be the appropriate ones for those who were called criminals. In our prisons to-day you will still hear the clank of leg-irons, you will be startled by the cries of distress and pain of those who are tied to the triangle, and you will observe one of your fellow-creatures, half-starved, walking up and down a dark and gloomy isolation cell, harbouring thoughts of revenge or despair! These examples of the inhumanity of man to man are quite common in some of our prisons, especially in so far as the treatment of native prisoners is concerned. You see, the slogan is " a kaffir is just a kaffir! "

The regulations are of general application—all prisoners are dealt with as if they conform to a single pattern or type—no discrimination is made for differences of character, education, personality or the many other characteristics which distinguish one human being from another. May I be permitted to illustrate my meaning by selecting just a few gems of " wisdom " which may give a fair indication of the great " humane feeling " underlying these regulations, e.g. a convict must (reg. 420 (1)) obey the orders of officers without reply or argument; he must (reg. 420 (2)) be quiet everywhere and at all times; he must (reg. 420 (17)),when marching in line, keep his head erect and his face turned toward the front; he must (reg. 420 (23)), in addressing an officer, say " Sir," and then proceed with his communication and remove his hat when addressing a superior officer.

Under this system work has to be found, otherwise it would be extremely difficult to keep the convicts " occupied at all times." Now this is how it has been and is done: The convicts are divided into various classes, primarily according to sex, and secondly according to race (reg. 349), and then there is a further classification on the respective criminality basis and progressive

stage systems (reg. 400)—the privileges which a convict may enjoy vary according to the class in which he may be put. Regarding the nature of the work allotted to prisoners, there are appointed for that purpose master tradesmen, trades assistants and trades warders (reg. 329) who see to it, that all trades are efficiently taught. The Director is, of course, in charge of the Prisons Department (reg. 5) and it would appear that the powers vested in him are practically absolute. All lawful directions issued by him must be promptly obeyed, whether in relation to the administration of the department, or in relation to the treatment of convicts or prisoners generally or the specific treatment of any convict or prisoner. He is also entitled by law to hire out services of the convicts or prisoners under sentence of hard labour to public bodies or private persons (Sec. 93 (1) of Act 13 of 1911) on such terms as may be agreed upon.

Convicts must, however, never be left idle, so the Superintendent must, subject to the approval of the Director, determine what shall be considered hard and what light labour at his prison. The determination of the particular labour to which any convict shall be put rests with the Superintendent, who may, in any particular case, confer with the Director and take his directions thereon (reg. 441).

All efforts at " reform " are virtually entrusted to visiting chaplains, who may, whenever possible, be appointed whenever the daily average of convicts belonging to any particular approved religious set or denomination exceeds twenty (reg. 132). This appointment is a personal one and the duties must be primarily of a moral and religious nature (reg. 133).

It is, however, the duty of the chaplain to forward by all means in his power the suitable re-employment of convicts on discharge and he must endeavour to keep in touch with them personally or by correspondence during the first month of release. For these purposes he is empowered to enter into communication with visitors' boards and other organisations and even to encourage the promotion of such bodies (reg. 139). One sees, therefore, that " reform " was left to religious and private enterprise.

By regulation 542, made in 1936, it is now provided, that the Minister may pay over to the Association entitled the " Social Services of South Africa," or any other approved organisation, any grant made by Parliament towards prison aid work in the Union. Some of the purposes of this organisation should be visiting and encouraging convicts in self-reform and aiding released convicts to live honourably (reg. 543 (a) (b)).

One of the bright spots in the present system established in 1911 is that all convicts may be permitted to have the use of literature for instruction or moral reform according to rules laid down from time to time and that a library may be provided in each prison (reg. 467 (1) (2)). Provision may also be made in every convict prison for the elementary education of illiterate

convicts, the subjects and hours of instruction being prescribed by the Director. As already mentioned, another notable reform has been the placing, by Act of 1934, of reformatories and hostels under the jurisdiction of the Minister of Education, thereby removing the taint of prison which formerly attached to juveniles convicted of anti-social conduct.

In the Pretoria gaol, where there are about seventy European first offenders serving sentences up to and including two years, the regulations are of a more generous and reformatory nature. There is a committee of visitors, which is the link between the prisoners and the outside world. Members of the committee have free access at all times to prisoners in their cells, so as to ascertain their needs, to study and influence them and to obtain employment for them after their release. A library is provided, and concerts and lectures are arranged, and even a radio is provided twice a week and table games are encouraged. Let me emphasise the fact that this only applies to European first offenders, and is a reform that has been introduced since 1911.

In a paper read by me on the 2nd October, 1936, at the National Conference on Social Work, I expressed myself as follows: " The real and sole object of punishment should be the protection of society, and the period of detention of the law-breaker is valueless to protect society unless the individual is induced to reform. . . . Society can only be protected from the anti-social conduct of some of its citizens in two ways, namely, either by devising means whereby the indivdual is taught to change his criminal tendencies so that he shall in future be no longer a danger or menace to society, or in the case of those persons who are proved to be incapable of any reformatory influences, segregation in certified institutions, if necessary for life, regardless of the gravity of the particular offence or class of offences that they show a tendency to commit. In other words, ' reform ' or ' segregation ' are the only effective methods to protect society from the anti-social conduct of some of its members. Few persons are so utterly bad that reforming influences could or would not have a beneficial effect on their character."

These opinions I still hold. The Archbishop of York in a recent article on " Penal Reform " says, inter alia: " The background of the probation system has been a much fuller appreciation of the fact that the criminal is a human being. By that I mean that society has recognised that a thief, for instance, is never only a thief; and least of all to be classified as a thief simply on the ground that on a particular occasion he stole " . . . " What you want is somehow or other to make the person who has suffered the consequences of his wrong-doing at the hands of society feel that it is inflicted upon him by a society which cares for his own welfare and hopes he may again become a useful and valuable member. . . . There must be no temptation to crime offered by special comfort and enjoyment of those in prison cells. Obviously not. It must be disagreeable in one way

or another and curtailment of liberty to any of us is a discreditable thing. But we must never adopt the principle of inflicting punishment as a mere balance for wrong doing. We must go forward the whole time on the principle that we are trying to consider not only what people are but what they can become. . . . ."

I have dealt somewhat fully with our system of punishment as embodied in the law of 1911 and regulations framed thereunder with two objects in view—firstly, to arouse public interest in the question of penal reform and to point out how backward we are and have been in benefiting from the truths of mental science and sociological research, and, secondly, to emphasise the contrast between our system and that adopted in practically all civilised countries when dealing with the punishment of their anti-social citizens. You will have observed that the humane carrying out of our system, in spite of the regulations, depends almost entirely on the personality of the Director, the Superintendent, the chief warder or gaoler. Now, as I said in 1936, it is not the officials who are to blame, but our law-makers, and those who are entrusted with the leadership in these matters. The improvements which our present Director has introduced in the treatment of prisoners and the manner in which the Superintendents and those immediately responsible for the carrying out of sentences have performed their duties, deserve the greatest appreciation and praise. In this respect I speak from personal experience gained from visits to practically every prison in the Free State and Transvaal. But what is needed is not a reasonable interpretation and a liberal application of the regulations, but an entire change and abandonment of a barbarous, wrong and purposeless system and the adoption of one which scientific research, experience and common sense have proved to be the correct one and most conducive to the welfare of the State. Why should we, a young country, not bound to any great extent by traditional doctrines, not be the foremost in availing ourselves of the progress of scientific research? England, one of the most conservative countries in the world, has recently set us a striking example. At the beginning of the present year the second reading of the Criminal Justice Bill was passed by the House of Commons. The preamble of the Bill reads: "To amend the law relating to the probation of persons by probation officers and the functions of probation officers, to provide new methods and to reform existing methods of dealing with offenders and persons liable to imprisonment; to amend the law relating to the management of prisons and other institutions and the treatment of offenders after sentence and of persons committed to custody. . . . ."

There are eighty sections of the Bill and the Committee stage has already reached section 32. One of the main objects of the Bill is to provide for the abolition of imprisonment as a method for the treatment of young offenders convicted by Courts of summary

jurisdiction. May I be permitted to cite some of the clauses which have already been passed in Committee: Clause 27 (1) provides: "A Court shall not impose imprisonment on any person appearing to the Court to be under sixteen years of age, and if he appears to be not less than sixteen years but under seventeen, he shall not be imprisoned, unless the Court certify that he is of so unruly a character that he cannot safely be detained in a remand home, or so depraved character, that he is not fit to be so detained. . . . ." Again: "A Court of Summary Jurisdiction shall not impose imprisonment on a person appearing to be not less than seventeen but under twenty-one years of age unless the Court has obtained and considered information as to the circumstances, including the character of the said person, and is of opinion that no other method of dealing with him is appropriate; and where the Court imposes imprisonment, it shall state the reason for its opinion that no other method of dealing with him is appropriate and the reason shall be specified in the warrant of commitment." Courts of Summary Jurisdiction may also be prohibited from committing such persons to prison for non-payment of a fine.

Clause 10 proposes to authorise the provision of special institutions to be called "Remand centres," to which young offenders remanded or committed for trial in custody are to be sent, instead of to a prison. Such Remand centres are to serve not only the purpose of custody but also the purpose of observation, that is, the making of such medical or other investigations as may be desirable in order to assist the Court in deciding how best to deal with the offender. Such Remand centres are to be available for persons from fourteen to twenty-three years of age

In addition to the remand homes provided by the local authorities for persons under seventeen years of age, the Secretary of State may provide "State Remand Homes" especially for medical observation as to the mental condition of the person

Clauses 12 and 29 make provision for Compulsory Attendance Centres and "Juvenile Compulsory Attendance Centres" respectively for persons between 17 and 21 years, and between 12 and 17 years. At present young people are sentenced for minor offences or committeed in default of payment of fines to short terms of imprisonment for a week or a fortnight or a month, and it is proposed to try the experiment in large centres of population of requiring such young offenders to attend at a Compulsory Attendance Centre at times when they would otherwise be at leisure during a half holiday or in the evening after work.

For young offenders between 16 and 21, who, in the opinion of the Court, do not require Borstal training but ought to be sent away for a time from their homes and from the places where they have fallen into bad habits or associations, it is proposed to try a system of "residential control" in institutions called "Howard Homes." Persons sent to such institutions will be under disciplinary conditions outside their working hours, but

during the working hours of the day will go out to ordinary employment.

Clause 31 deals with a sentence on a young person between 16 and 21 years, to undergo a period of discipline in a Borstal Institution, if the Court is satisfied that by reason of the offender's character and habits it is expedient to pass that sentence with a view to his reformation and the prevention of crime.

Corporal punishment has been abolished (Clause 32) except for very serious prison offences; the term " hard labour " has been eliminated from the Statue Book (Clause 33); and the legal distinction between imprisonment and penal servitude has been abandoned. There will be no more convicts or convict prisons in England.

The Bill also provides for sentences of corrective training and preventive detention (Clause 34). From the newspapers I also learn that capital punishment has been abolished for an experimental period of five years.

There may be those among you who will call the proposed measures revolutionary—but that would not be correct. They would only be revolutionary in the sense that it has been possible to introduce these reforms in conservative England. In most of the civilised countries of the world, as already mentioned, penal reform in the sense above proposed has long been an accomplished fact, and the results have been most startling. Just to quote one instance: In the " Sunday Times " of the 30th April, 1939, the following news item appears (I took the trouble of enquiring of the Editor whether the news, not being of a political nature, was reliable, and he assured me that it was true). The paragraph says: " It will soon be possible to demolish Sweden's largest prison—the Langholmen in Stockholm—without having to build a new one in its place. This is due to the big reduction in the number of criminals as the result of many penal reforms. In the course of a conference on the Depopulation of Prisons, M. K. Schlyter, President of the Court of Appeal, declared that, since the introduction in 1931 of the new system of fines—whereby the fine imposed varies according to the financial status of the defendant and payment is thus made easier—the number of cases in which the sentences had been a fine instead of imprisonment had been reduced from 13,350 to 4,700 in 1938. Other penal reforms which had contributed to the reduction of the number of convicts were the special corrective training centres for young offenders, the ' protective asylums ' and the revision of the penal code on humanitarian lines."

In the " Pretoria News " of the 5th May, 1939, the following interesting news item appears: " That in reform schools in this country a policy based on trust is more effective than one based on deterrents has been proved by the East Moor School at Adel, near Leeds. It may surprise the visitor to discover that there are neither bolts nor bars, that access to the surrounding countryside is free, that there is a total absence of warders, that

boys are given leave to go to the cinema, that the keeping of pets is encouraged, and that pocket-money is distributed regularly. Results show that these measures are several times more effective than the original methods of regulations and restrictions. There are 128 boys, aged from 15 to 19, and it is no exaggeration to say that they live in a harmony equal to that of many of our public schools "—and so on.

It is one thing to discard a bad system and to introduce a new one, but you will not achieve the desired beneficial results unless you also see to the proper carrying out of your new system—in other words, unless the machinery you provide is efficient. In my opinion the reason why the defects of our present system have not been condemned or exposed long ago is largely due to the fact, as I have already mentioned, that our present Director and those immediately responsible for the carrying out of the sentences of the Court, have interpreted and applied the present regulations in as humane a spirit as was possible for them to do. It will have been gathered from the regulations above mentioned, that the present system forbids the prisoner from having any *human* contact with his officer—and vice versa. He must obey all orders—not talk or argue—stand at a distance, not even breathe unless he is two paces distant from his officer—salute—walk head erect—look always forward—never laugh—always remain silent and so on. For this class of disciplinary work the present officials are quite competent and I admit that ,from my experience, these officials are on the whole a very fine body of men, and perform their duties in a highly creditable manner.

When visiting prisons I was immensely struck by the military correctness of behaviour of the warders—one passes through a human chain of officials standing to attention, clicking heels and saluting. All this is, no doubt, very gratifying and flattering to those who are accustomed to this kind of thing. In my opinion this exhibition of military discipline in a prison where the spirit of reform ought to prevail and the ordinary and natural characteristics of human behaviour should be encouraged, is quite out of place—respectful behaviour is not and never will be evidenced by the clicking of heels and the raising of hands in salute! The qualifications required of subordinate officers are at present, no doubt for the reasons which emerge from the class of work demanded of them, not very high. (See reg. 140). Educationally, standard six is regarded as sufficient and even this may be waived. Then there is a curious regulation which excites one's sense of humour. It is reg. 28 (8) which reads: " Officers are recommended to read the books on penology supplied to libraries to enable them to carry out their duties more intelligently and to increase the value of their services to the Government." Note, it is only a recommendation—there is no compulsion—what particular books are referred to is left in the dark—and the libraries where these books are to be found the officer must

discover for himself! I wonder what these books were in 1911! When once, however, an officer has absorbed the knowledge gained from these books, regulation 28 (18) provides "that he shall not publish a book or article on matters relating to the Prisons Department without the written permission of the Director;" furthermore, he is not allowed (reg. 28 (17)) to make any unauthorised communication whatever to anyone about the prison or prison administration.

Now, the question of the vocational training of penitentiary officials has received careful consideration in those countries where the new ideology has been accepted and acted upon. The International Penal and Penitentiary Commission of the League of Nations in 1938 drew up and submitted a memorandum on the subject to the various governments and its recommendations are a most valuable contribution towards a solution of the problem. A few extracts would be illuminating. It says: "The task of officials placed in charge of, or attached to various services in the penitentiary institutions can no longer be confined in any country to the conscientious supervision of the prisoners, but must everywhere comprise the duty of judiciously exercising, by their persons and conduct, as educational influence as possible on the prisoners, some of whom are exceedingly difficult to handle both individually and in the environment of penitentiary life. The moral character of the prison which, more than anything else, ultimately determines the effect of internment on the prisoner, will be vitally influenced by the spirit, attitude and activity of the staff. . . . ." "It is particularly important that persons recruited as penitentiary officials should fully understand their responsibility both towards the prisoners and towards society and are therefore in a position to realise that the object of their work is, as far as possible, the re-adaptation of prisoners to social life and that this object demands close and loyal co-operation of all the officials of the prison in the same spirit." . . . . "Indeed it must be required of the officials that they should possess high intellectual and moral qualities in order to obtain the desired success of these new institutions which aim at the prevention of delinquency. . . . Special training must also be instituted of such a nature as to give the necessary theoretical and practical knowledge. . . . . Penitentiary officials, faced by highly different situations arising out of the problems as numerous as the problems of life itself must, therefore, not only have a good general education and, in the highest posts, even a very high education, but must also possess a number of personal qualities which are not usually combined in one person. They must have intelligence and be good-natured; they must have a generous disposition and coolness; they must be polite and kind while remaining firm, just and free from all sentimentality; they must have a keen social sense, a highly developed critical sense and a pronounced sense of order; they must be capable in their work, must be able to maintain discipline and must themselves be

disciplined. They must understand how to adapt themselves to the common management, to follow the lines laid down by the management for the treatment of prisoners and regard themselves as more or less important wheels in the organisation, all of which are necessary for the proper functioning of the common work. All the officials must know how to act in every way so as to be a good example in every respect for the prisoners. . . . . The definite appointment of the penitentiary official as such must ensure him a stable and permanent position in the service of the State. . . . . They must receive fixed salaries, the amount of which is settled for the various posts and ranks in the various branches of the service in proportion to the relative importance of the functions . . . . and lastly, it is of importance that the members of the staff may look forward to receiving a reasonable pension when they have reached the retiring age. . . . ."

I heartily agree with these recommendations. Even under our present penal system their acceptance would greatly improve matters in spite of the law and the regulations.

Another matter which requires urgent attention even having regard to present conditions, is the question of our prison buildings and the nature of the accommodation provided.

Architectural science seems to have reached a state of absolute stagnation when it has to deal with the building of prisons, presumably due to the fact that the designs were dictated by the antiquated and mediaeval conception of crime and its punishment. There has been an absence of imagination and a lack of vision; most of our country prisons still follow the dungeon pattern—thick iron bars, slits of windows, no sun, faulty ventilation and semi-darkness in the cells. The prisoner was considered to be a dangerous caged animal whose escape at all costs must be prevented. Hygienic conditions were in these circumstances of minor consideration. Even our Central Prison in Pretoria seems to be a patch-work construction and shows little advance on antiquated patterns. One thing must be admitted, and that is, that our prisons are kept scrupulously clean. Overcrowding, however, especially of the native quarters, is of much too frequent an occurrence. As environment plays such an important part in the life of the human being and has a direct beneficial influence or otherwise on the formation of character and his moral uplift, there is no reason why, in sunny South Africa, you should not strive to improve your prison architecture and instead of allowing your prisons to be an eyesore to the community, make them artistic structures. One must not think because one is advocating better housing for our unfortunate fellow citizens, that one desires to provide a sumptuous hotel for delinquents. The loss of liberty is already a serious hardship to anyone and if you wish the anti-social member of the community to become a useful member and so protect society in future from his criminal conduct, then you will be well advised to see to it, that his environment is such as to create a feeling of contrition and steel him in his resolution to remain outside prison walls.

In my travels round the world I have had an opportunity of visiting many prisons—in England, the United States, the Argentine, India, etc., and everywhere I found a change of spirit in the administration of prisons and in their construction, and it was with a sense of shame that I recalled to mind some of the ramshackle structures, dating from the year " 0," in my own country—especially considering the fact, that we, with our gold mines, are the richest country in the world.

This matter of a change of architectural design in the building of prisons has been commented upon by me repeatedly and from time to time, especially when, in my judicial capacity, I visited country prisons, and although the present Director is aware of the imperfections and has done much to remedy matters, there is still much to be done in this respect.

I hope it has been clear from what I have said, that so far I was dealing almost exclusively with European delinquency and not with the problem as it affects the native population. A cardinal fact in this connection which has been either ignored or often not sufficiently recognised is, that, although we have many native " prisoners " we have but few native " criminals." The Assistant Director of Prisons, Mr. Blankenburg, recently gave the figures of the prison population and also made pertinent remarks on the subject of native crime. In 1938 there were 157,503 sentenced prisoners admitted to gaol. Of these there were 117,122 native men, 16,696 native women and 3,365 European men. No less than 111,407 were admitted to prison with sentences of one month and under, and native tax cases accounted for no less than 54,932 or 66·21 per cent. of the total native male admissions of one month or less. These figures speak volumes and I have no hesitation in saying that the Pass law system, Tax law enforcement and other bye-law contraventions are responsible for about 90 per cent. of our native prison population. We have literally made criminals of our natives in the widest sense of the term—namely, persons who have been sent to prison. When is this going to stop? " Pass-laws " serve no protective purpose. They are a convenient machine to tax the employer and a lucrative method to extract money by way of fines out of the poor bewildered native. The sooner we abolish the present Pass-laws and introduce a system of identification certificates, the better it will be for the native population. There is no justification for using the native as a victim or pawn in the enforcement of an employers' tax—other methods of imposition and collection are surely feasible. Why is it not possible for our rulers and officials to break away from obsolete laws? A little courage and vision is required to remedy this injustice. The Native Tax at its present figure, in view of the low wages earned by natives, especially on the farms, is a burden, which economically, is of a crushing nature to the native. The very fact, that 54,932 natives were sent to prison as tax defaulters is a blot on the present native administration. In 1936, of those convicted

and sent to prison 23,428 served the full period of their sentence and only 7,065 were able to pay their tax and fines. This scandal had become such a grave one, that a departmental committee of inquiry was appointed, which in February of 1938 made a report wherein other methods of collection of tax have been recommended, obviating the necessity of making criminals of those who failed timeously to pay their tax. The principle underlying the report is that everything possible should be done to keep our natives out of prison for offences of a technical nature. But why was this not thought of years ago? Legislation is fortunately now being introduced to give effect to the recommendation of this committee. It is estimated that each year the amount of tax not paid comes to nearly £250,000 and that the cost at present of maintaining in prison the many thousands of tax defaulters amounts to at least from £50,000 to £60,000 a year. The greater proportion, however, of this expense is recovered from the labour of these short-time prisoners.

In view of the already heavy burden of indirect taxation that the native has to bear, the entire abolition of this tax, or certainly, in my opinion, a substantial reduction thereof, deserves the immediate and earnest consideration of the Department of Native Affairs. It is calculated that this direct tax on the native, taking into consideration his average yearly income, is three or four times higher that what the European income taxpayer is called upon to contribute to the revenue of the State.

I think that I would be within the correct limits, if I were to say that the actual yearly number of natives constituting our criminal or anti-social population would be about 10,000, consequently it is only with these that the system of penitentiary treatment would be mainly concerned.

In my view there is one fallacy which should be dispelled from the European mind. Colour prejudice in South Africa and an erroneous belief in superior civilisation of the European have created a conviction that the native is a barbarian, devoid of all social instincts and culture. Prof. Renter in his book "Population Problems," says that scholars now all accept as a fairly well-founded hypothesis the position that the various races and peoples of the world are essentially equal in mental capacity and capacity for civilisation. It is true that the native shows certain physiological and psychological differences from the European, but the differences are rather of degree than of kind, and such peculiarities are not always a sign of deficiency or retardation.

The native has evolved his own form of government; his laws, based on custom, show a deep appreciation of social values, he is naturally law-abiding and conscientious. His observance of communal responsibilities is remarkable. His sense of justice is as innate as that of the European and his courts for the enforcement of rights or the punishment of anti-social members are usually conducted with fairness and impartiality. We should get rid of the idea that the native is unable to reason and to think

things out for himself—that he is mainly interested in the acquisition of food—protection from his enemies—comfortable housing and sexual liberty. There is undoubtedly a recognised code of law founded on principles of justice if we come to examine the native laws affecting murder, adultery, theft and many others. Havelock Ellis in his book "The Criminal," says that among primitive races criminality in the true sense is rare—criminality waits on civilisation. When we talk of criminality among native races we cannot use this term indiscriminately. The native has an entirely different view from our own. In many ways the primitive native (not the native who has long been in contact with Western civilisation) resembles the child in his want of forethought and inaptitude for sustained labour In examining the so-called native criminal in order to ascertain whether he is really a criminal at all, one should have regard to the fact whether, according to his own view and that of his community, he is perhaps not merely performing some act which is not accepted as anti-social by his own people. We can therefore divide the native criminal into classes as in the case of the European, namely, the political criminal, the criminal by passion, the instinctive criminal, the habitual criminal and the professional criminal. Even prison officials have to admit that few criminals are really benefited by their period of incarceration. Prison seems to be largely a machine without discrimination of feeling, centralised in its control and responsibility, which deals with human inmates in a manner which reduces them to a uniform level of disciplined animals. Its regular life, its monotony, its long periods of incarceration, act so depressingly as to often render its inmates unfit to live afterwards in the society of their fellow creatures. When we consider that the native population in this country far exceeds the European, and that these people by their work are providing a substantial proportion of the revenue of the country, then on that ground alone, we must confess that they have a strong claim to participate in the benefits which scientific investigation into the causes of crime has brought to the criminal classes. There can be no doubt but that the native criminal is actuated by the same notives as the European. Unfortunately we are so blind as not to see that the native is the mainstay of our industrial wealth and that without him we would not be able to carry on our industrial activities. The native does not understand our Court procedure. He does not appreciate the importance or sanctity of the oath and in his tribal courts the methods employed to arrive at the truth and to expose false evidence are quite different from those employed in the European courts. Miscarriages of justice are consequently of frequent occurrence and I have it on the best authority of those who have had an opportunity of investigating the matter that approximately ten per cent. of the natives executed for murder

were actually innocent of the crime, due principally to the circumstances abovementioned. Some of these natives might have been guilty of the lesser crime of manslaughter but legally not murder. There are but few Europeans who understand the native mentality—one must have lived among them and speak their language before one can fathom their mode of thinking and reasoning.

Now, the question will be asked, what do we do to rehabilitate the anti-social native? It will come as a surprise to you to learn, that the prison regulations which I have mentioned only in a general way apply to native prisoners. There are in fact no concrete and definite regulations which apply to natives; not a thing is being done officially to bring about their reform. There are approximately 700 native prisoners in the Pretoria gaol. The only moral uplift they experience, or spiritual comfort they receive, is due to the self-sacrificing efforts of the Swiss Missionary (about 90 per cent. are under his care) and of the other ministers of the various religious denominations. They are in one respect, however, better off than the European prisoners in that they perform most of their prison labour outside and in the fresh air. The colour bar prejudice and trade union tyranny prohibits the officials from even attempting to uplift the native by teaching him some kind of trade. We have no right to deny the native an equal opportunity to develop in the economic field. The outcry that we should maintain a White South Africa is the stock-in-trade of the politician and selfish agitator. The non-European does not seek social equality, but only a right to live and develop on civilised lines; and reason and justice must concede him that right. At present the native prisoner is doomed to be the manual, unskilled labourer and his work is not only being exploited by the State, but it has even become a source of revenue during the time of his incarceration. A state of affairs which is truly a blot on our much vaunted civilisation! The time is long overdue for those in responsible positions to do something to remedy matters. The native prisoner is as much entitled to remedial treatment as the European, although, as I have already pointed out, even the latter, under the present system, receives but scant attention.

In conclusion, I want to say that it is my firm conviction that the present procedure whereby the presiding officer in our Courts measures out the punishment which should be imposed for a particular crime, fails in securing that immunity and protection of society which should be the main object of punishment. The function of the Court should cease when once the fact of guilt has been ascertained and when on the report of the probation officer it has been established that the delinquent should be segregated. The accused should then be handed over to a board, composed of expert psychiatrists and of men with a profound knowledge of human nature, to determine the period

of detention, which should vary in length according to the personality and character of the delinquent and the probability of his responding to reformatory treatment. Each anti-social individual will have to be dealt with separately, and there may be and certainly are, many cases in which it might be advisable, for the protection of society, that, no matter what the nature of the offence, an indefinite period of segregation may be necessary. We have, for example, many social parasites who are highly educated and who abuse their talents for the purpose of preying on the credulity of the public; it would be foolish to allow them to run riot again after a short term of imprisonment because they would only utilise their superior knowledge to continue their depredations and evade detention. The class I have principally in mind is the swindlers, the fradulent stock-exchange manipulators and company promoters, the share pushers and other anti-social persons who make a profession of fraudulent dealings and by their plausible and glib tongues cause the ruin of unsuspecting members of the public. In other cases, however, where social conditions are principally to blame for the downfall of a citizen, society should give that person that chance which has been denied him and do everything in its power to restore him to the ranks of useful and valuable members of the community.

Before concluding I would like to express my deep appreciation to Mr. Blankenburg, the Assistant Director of Prisons, and to Mr. Crux, the Superintendent of the Pretoria Central Prison and Gaol, for the courtesy extended to me by giving me an opportunity of again visiting and inspecting these institutions and also for valuable information supplied to me.

I may summarise the conclusions I have come to as follows:

(1) The doctrine of retribution and revenge, which is still largely the basis of criminal law in this country is out-of-date and obsolete. The progress made by mental science and sociological research during recent years and the lessons of practical experience, have established the fact that this system as adopted and applied, has had neither the result of materially preventing crime, nor of effectively safeguarding the community from recurrences of anti-social conduct in those who have been punished for wrong-doing.

(2) The object and aim of punishment for crime should be the protection of society from its ani-social members. This can only be achieved in two ways; either by subjecting the wrong-doer to such treatment as would bring about his " reform " and hasten his return to society as a useful and law-abiding citizen, or by segregation or detention for an indefinite period of those who show themselves either incapable to reform or who exhibit such pronounced criminal tendencies that it would be a danger to society to allow them to go free.

(3) The existing prison regulations which lay down the policy for the treatment of those undergoing punishment in our

penal institutions, should be repealed without delay and should be replaced by more humane rules which should embody those principles of reform which are in accordance with the truths revealed by the great advance of mental science during recent years and which have already been adopted and embodied in the legislation of most civilised countries.

(4) The new rules should be applicable to Europeans and non-Europeans alike with such modifications as may be necessary, having regard to the difference in mental outlook and civilisation of the two sections of the community.

(5) Our neglect of the interests of the non-European prison population and the short-sighted policy in dealing with the problem affecting their reform and rehabilitation, is a grave reflection on those who should have given a lead to the public in those matters. The industrial and economic boycott of the native, resulting in an increase of poverty and the lowering of the moral standard of the non-European, has, and must have, largely contributed to the increase of crime amongst them, and a radical revision of the laws in this respect is long overdue.

(6) Criminal Court procedure as applied to the native is unsuitable and often leads to a miscarriage of justice. Steps should be taken to establish native courts for the trial of natives. Only those Europeans should be allowed to take part in the proceedings and constitution of such courts as are fully acquainted with the native languages, and, through experience and education, possess a thorough knowledge of native law and customs and have gained an insight into native mentality.

(7) No sentence of imprisonment should be imposed on any person appearing to the Court to be under sixteen years of age; and no sentence of imprisonment should be imposed on any person under the age of 21 years unless the information obtained and considered leads to the conclusion that no other method of dealing with him would be appropriate.

(8) Young offenders should be dealt with in such a manner that the taint of prison and of criminal conviction are as much as possible avoided. Reformatories and the other special institutions suggested in the present Criminal Justice Bill in England, should be established; for example "Remand Centres," "State Remand Homes," "Compulsory Attendance Centres," "Howard Homes," and such like.

(9) Imprisonment as an alternative to the non-payment of a fine, should be abolished in all cases (whether European or non-European) where the alleged offence is of a technical nature, e.g., contravention of regulations, rules, bye-laws, and such like. With regard to the native population, in respect of most of the contraventions of the Pass laws, Native Tax laws and other regulations specifically applicable to them, imprisonment, in default of payment of fine, should be abolished. To enforce the payment of the fine imposed, other methods of enforcement should in all cases be devised.

(10) The functions of the Court in cases of serious crime should be confined to the establishment as a fact of the guilt or innocence of the accused; then, in the event of conviction, after having obtained and considered the report of the probation officer, the Court should decide whether it would be just and expedient for the protection of society to detain the convicted person in some prison or other appropriate institution. The decision as to the period of detention and the mode of treatment should be left in the hands of a board composed of psychiatrists, and other persons who are competent by reason of their experience of human nature or otherwise, to deal with the problem.

(11) For the prevention of crime and the protection of society, the State should provide separate institutions and devise special methods of dealing with the wont-works, the parasites, who although not mentally defective through lack of education or balance, may become, or are, a burden and menace to society, the sexual deviates, and other abnormal persons.

(12) Corporal chastisement and hanging as punishments, should be abolished, as experience has revealed the fact that they are ineffective and practically useless in causing the prevention of crime or its recurrence.

(13) Leg-irons and chains as a means of enforcing prison discipline should, as being a barbarous and degrading method, be discontinued immediately. and solitary confinement in an isolation cell, with or without spare diet, as a punishment, should be abolished.

(14) The architectural design and construction of our prisons should be radically altered, and the buildings should be so planned as to be in keeping with the recognised and enlightened policy, that environment is a potent factor in the moral uplifting of the human being and in the formation of his character.

(15) The Probation system should be extended and more Probation Officers, male and female, should be appointed. Their duties should be clearly defined. Social Service organisations should be encouraged and the State should suitably and adequately subsidise all such bodies, whose work is specially concerned with the prevention of crime and the after care of discharged prisoners.

(16) The qualifications of the Prison Staff should comply, as near as possible, with the requirements as laid down by The International Penal and Penitentiary Commission of the League of Nations in its memorandum submitted to the various governments in 1938.

(17) With a view to the speedy carrying out of penal reform, as adopted and applied in most civilised countries of the world, I suggest that a small commission, of not more than three persons, be appointed to study the whole question and thereafter to make such recommendations as are especially suitable to the requirements of the Union.

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A SURVEY OF THE ULTRAVIOLET SOLAR RADIATION AT JOHANNESBURG

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With 21 Text Figures.

Read 4 July, 1939.

I. Introduction.

The importance of sunlight to plant and animal life cannot be too amply stressed. It has been an environmental factor throughout the process of evolution of life and health processes of living things. The question of the effect of sunlight on man, especially the white races, settled in tropical countries, has lately become of great importance Some scientists hold that North European types tend to degenerate physically when transplanted into tropical areas, and experiments in the Union on British cattle covering several generations actually show a progressive deterioration of bone and other tissues. Apart from the value of the study of the ultraviolet solar radiation as an aid to therapeutic treatment, these rays are of importance also because of their physical nature and characteristics, as shown by the increased number of publications on the subject during the past decade.

The methods used by biologists and physiologists are generally photo-chemical in nature, being inexpensive and simple as far as manipulation is concerned; the results are easily obtained. The accuracy, however, is rather low and the results merely serve as a guide to the total amount of ultraviolet light received. For the study of the physical nature of this light, more accurate methods are employed involving the use of the bolometer, photo-electric cell or spectrograph. These enable us to obtain a detailed knowledge of radiation intensities and the conditions affecting them at any particular time.

The previous work done in South Africa (1) was of the nature of a preliminary survey using a photo-chemical method. The results obtained indicate that our sunlight has a higher ultraviolet content than places in Europe and America. The following investigations were undertaken with the intention of obtaining more accurate data regarding the physical nature of the rays, and of comparing the results with those obtained overseas. The apparatus was set up in the grounds of the Rietfontein Hospital, which is near Johannesburg and has a latitude of 26·2°S, and an altitude of 5,370 feet. Readings were started in May, 1938, and continued for a year.

II. Apparatus.

Three argon filled cadmium cells of the Elster and Geitel type were used in conjunction with a string electrometer. All the apparatus was manufactured by the firm Gunther and Tegetmeyer.

Fig. 1.

A cell for measuring the direct sun's rays.

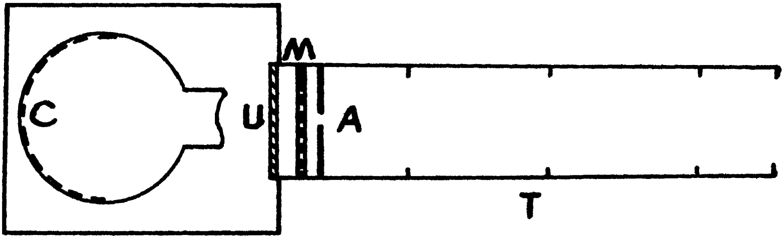

Fig. 2.

Cadmium cell for direct sunlight.

C, Cadmium cathode of photoelectric cell.
U, Uviol glass filter.
M, Minos glass filter.
A, Aperture.
T, Extension tube.

The cells are so constructed that each can be fitted to, or removed from, the electrometer within the space of a few seconds and without disturbing the setting of the electrometer. Two of the cells are for observations on direct sunlight only, while the third can be exposed to both the direct sun's rays and the sky radiation at the same time.

(a) *Direct Sunlight Cells.*

The first type receives the radiation from direct sunlight at normal incidence restricted by an extension tube to a cone of semi-vertical angle 5°. Diaphragms containing circular apertures of various sizes are inserted in the cell end of the extension tube so as to give a discharge time of about 10 seconds. These apertures were carefully calibrated in terms of a given aperture for the cell. Fig. 1 shows one of the cells connected to the electrometer and the relative positions of the various parts of the cell are drawn in diagrammatic form in Fig. 2.

In order to keep the cells dry, small glass bulbs are attached to the metal cases. Into these drying powders are placed. Insulation tests were always made when the apparatus was in use, but, owing to the dry climate, it was usually found that the cells held a charge when connected to the electrometer.

The difference between the two direct sunlight cells is one of spectral response. The older of the two, called Cd X, has permanently attached a filter of uviol glass, the effect of which is to give the spectral response curve a steeper fall near the lower wavelength limit. This cell responds to energy of wave-lengths below 3350A, with a maximum response at 2900A. The newer cell, Cd Y, responds only to light of wave-lengths below 3150A and has no filter attached.

In Fig. 3 the spectral response curves for the two cells are shown. These were obtained at the Strahlenfurschungsinstitut

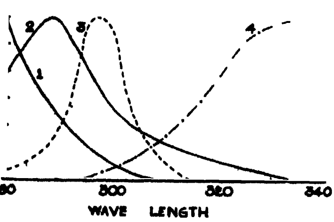

Fig. 3.

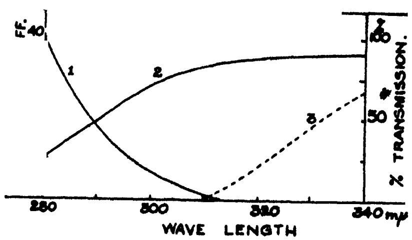

Fig. 4.

Fig. 3.—(1) Spectral response curve of Cd Y.
(2) Spectral response curve of Cd X with uviol filter.
(3) Erythemal curve for untanned skin.
(4) Solar energy distribution curve.

Fig. 4.—(1) Ozone absorption curve.
(2) and (3) Transmission of Uviol and Minos glasses.

of the Berlin University. The method used was to measure the energy of different lines in the spectra from cadmium and mercury lamps by, firstly, a double monochromator with bolometer and, secondly, the cadmium cell connected to a calibrated galvanometer. The ordinates of the two curves are proportional to the quantity of electricity produced by the cell per unit incident energy. In the same figure are shown the spectral erythemal curve for untanned skin (after Coblentz) (2), and the solar energy distribution curve (after Pettit) for noon during midsummer at Tucson (3). The ordinates of all these curves are only relative to each other and were chosen to give each curve a convenient size. The effect of the uviol glass filter on the Cd X cell is really to make its response correspond more nearly with the erythemal curve. This type of combination has been found to be the most suitable of all methods for evaluating biologically active rays.

(b) *Ball Type Cell.*

The third cell, shown in Fig. 5, consists of two concentric spheres of ultraviolet transmitting glass. The outside of the inner sphere is coated with cadmium to form the cathode, and around this in the form of a wire grid is the anode. The observation station is so situated that this cell can receive rays unobstructed from all parts of the sky. Its spectral response curve coincides nearly with that of the Cd Y cell.

Fig. 5.
The ball type cell.

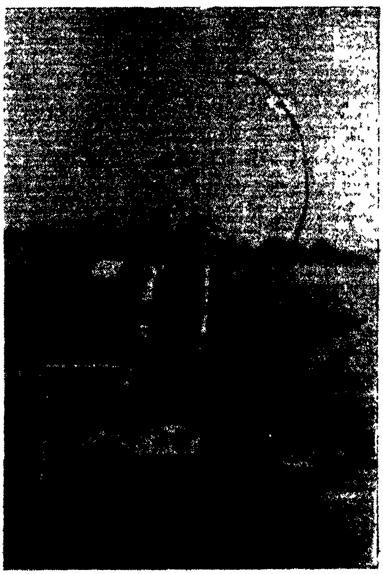

Fig. 6.
The ball cell with shade.

III. Method.

The method consists of taking the time for the anode of the cell to fall in potential from 70 to 65 volts when exposed to ultraviolet light. The readings are then reduced to an arbitrary scale by the formula:—

$$R = \frac{1000}{t\,f}$$

Where, t is the observed time for the voltage drop,

f is the ratio of the effective area of the aperture used to that of a given aperture for the cell.

R is a number which is proportional to the intensity of the ultraviolet solar radiation as registered by the cell.

Readings were taken only on clear days at half-hour intervals after the sun had reached an altitude of 20°. The time was corrected to true solar time and plots were made showing the diurnal variation of intensity for each cell.

IV. Calibration to Standard Units.

The readings given by Dorno's Cd II. cell at Davos is generally accepted as an international standard for all cadmium photo-electric cells of a similar type. Thus in order to compare intensities measured by different cells, it is necessary to reduce the readings obtained by them to the arbitrary units of intensity as measured by Dorno's cell. The "Davos unit" is the solar intensity which will produce a current of $3{\cdot}5 \times 10^{-11}$ amp. in the standard cell.

The Cd X cell used at Rietfontein has been compared directly with this standard cell. The method of calibration was developed by Drs. Levi and Mörikofer (9). In this, two sets of readings are taken each time with the cell—one with a minos glass filter attached to the cell and the other without this filter. The ratio of the reading taken without the filter to that taken with the filter is called the Minos Ratio. It was found that the factor for converting the cell readings "R" to Davos units is a function of the minos ratio.

The minos glass absorbs all rays below 3090A, which is the wave-length at which ozone absorption commences. Thus, all measurements taken with the filter are of rays unaffected by the ozone layer. Fig. 4 gives the percentage spectral transmission curves of the uviol and the minos glass filters, together with the ozone absorption coefficient for different wave-lengths.

Fig. 7 represents the curve obtained by Dr. Levi showing the sensitivity ratio of Dorno's Cd II cell to the Cd X cell for minos ratios from 5 to 10. It is the mean of readings taken during the period 1930 to 1932 using the two cells side by side at Davos.

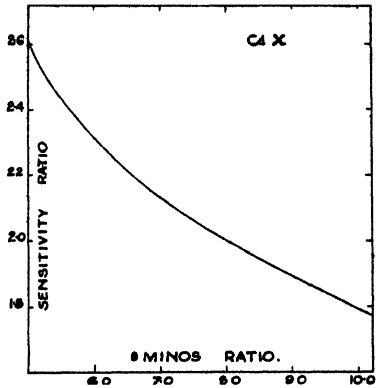

Fig. 7.

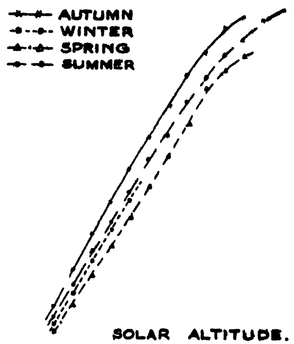

Fig 8.

Fig. 7.—Showing the relation of the Minos Ratio to the factor for converting the Cd X cell readings to Davos units.

Fig. 8.—Showing the seasonal means of the ultraviolet intensities in Davos units for different solar altitudes.

V. Results.

(a) *Direct Solar Radiation.*

The times of day corresponding to solar altitudes of 20°, 25°, 30°, etc., were obtained for each day from graphs. These were drawn on log. paper from a knowledge of the time of sunrise and the sun's altitude at midday. The intensities corresponding to these solar altitudes were read off from the daily curves of each cell.

Table I gives the monthly means of the ultraviolet intensities in Davos units for the Cd X cell for different solar altitudes. It can be seen from the table that for each sunheight there is a maximum intensity in the autumn months with a minimum in the spring, which is the inverse of the change in thickness of ozone in the upper atmosphere. This variation is shown graphically in Fig. 8, where the seasonal means of the intensities from Table I are plotted against sunheight. The corresponding figures for the Cd Y cell show a 10% larger variation between the spring and autumn intensities. This is what would be expected, since this cell responds almost entirely to energies of wave-lengths which are absorbed by the ozone. If the response curve of Cd Y in Fig. 3 is compared with the ozone absorption curve in Fig. 4, the similarity will be apparent. They are both of the same form and both commence at the same wave-length.

The monthly means of the ultraviolet solar intensities in Davos units at each hour of the day are given in Table II. The intensity at 8 a.m. on a day in June is less than one-twentieth that at the same time on a day in January, but at midday the ratio becomes two-fifths. Also, the intensity at 8.00 a.m. in

TABLE

Sunheight	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°
1938														
May ...	42	82	119	159	201	255								
June ...	34	71	107	144	181									
July ...	26	62	100	138	178									
August ...	22	61	101	142	180	224	258	308						
September ...	21	54	91	131	166	202	242	286	330					
October ...	22	51	86	119	157	195	242	286	323	352	371			
November . .	25	66	103	140	179	223	253	262	324	353	375	391	406	
December ..	49	89	128	163	197	234	270	296	336	372	405	428	448	463
1939														
January ...	53	98	137	176	217	250	286	323	357	372	408	429	443	457
February ...	69	112	157	200	242	284	318	350	376	403	424			
March . .	63	113	157	201	241	279	316	351	380					
April ...	42	83	125	168	206	246	286	337						
May ...	41	82	119	160	200	247								

Monthly averages of ultraviolet intensities for different sunheights in Davos units.

TABLE

Monthly averages of ultraviolet intensities in Davos units for each hour of the day.

Time	a.m. 7	8	9	10	11	12 noon	p.m. 13	14	15	16	17
1938											
May		18	102	178	222	247					
June		8	64	129	173	189	170	128	65		
July		7	59	118	161	181	173	125	63	13	
August		12	105	186	246	265	248	186	101	17	
Sept.		46	138	223	285	307	279	219	144	50	
October		90	192	289	356	380	354	281	171	78	
Nov.	34	136	239	325	384	406	377	315	222	128	30
Dec.	73	173	270	368	444	463	428	350	252	170	75
1939											
Jan.	75	177	278	367	427	454	429	368	279	177	73
Feb.	52	158	273	357	412	431	407	358	275	158	52
March	20	128	239	326	383	402	383	323	237	131	25
April		61	161	243	304	339					

Unfortunately the afternoons during May, 1938, and April, 1939, were either cloudy or

the summer is the same as the intensity at midday in the winter. The extreme ultraviolet in sunlight as registered by the Cd Y cell does not make its appearance felt until after 10·00 a.m. in winter, yet in summer the cell is affected long before 8 00 a.m.

(b) *Comparison with Overseas Results* (4, 5, 6, 7, 8).

Fig. 9 shows the mean intensities for the year in Davos units plotted against solar altitude. On the same graph are shown all the results obtained so far by other observers in Europe, India and Egypt. The curves show that the intensities at Rietfontein are practically the same as at Davos for the same sunheights. Thus the air here must be extremely clear, permitting a relatively large amount of biologically active rays to penetrate, although, however, the amount of ozone at this latitude is probably less than in Central Europe. In all other countries where observations have been made the intensities are lower than those at the famous health resorts at Davos and Arosa in the Alps.

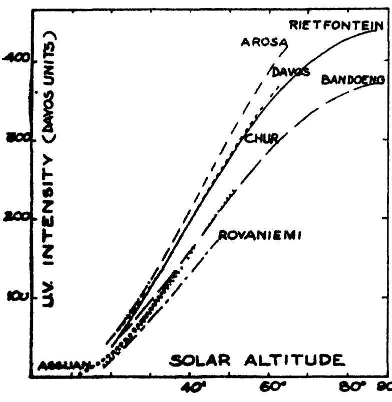

Fig. 9.

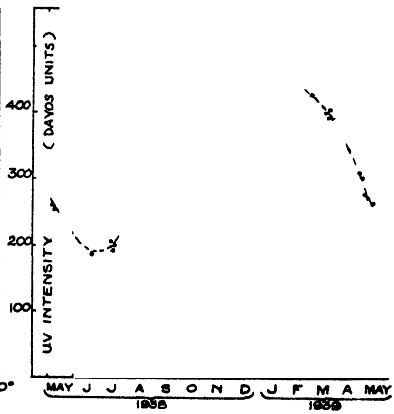

Fig. 10.

Fig. 9.
- ——·—— —— Arosa, 1860 m., 47°N.
- - - - - - - - Davos, 1560 m., 47°N.
- . . . . Chur, 590 m., 47°N.
- ———————— Rietfontein, 1760 m., 26°S.
- ——— ——— Bandoeng, 760 m., 7°S.
- o o o o o o o Assuan (winter), 100 m., 24°N.
- — – —— – — Rovaniemi (summer), 90 m., 66°N.

Fig. 10.—Showing the variations of the noon ultraviolet intensities in Davos units at Rietfontein throughout the year.

(c) *Midday Intensities.*

The noon intensities in Davos units for very clear days at Rietfontein are plotted in Fig. 10. The resulting curve indicates that the curvature about its minimum value is greater than that

about its maximum. This effect is produced by the variations of the sun's daily culmination in altitude during midsummer and midwinter.

For high solar altitudes such as occur in summer, small variations in the culmination produce only very small changes in the length of air path traversed by the rays. This length of air path is called the air mass, and is proportional to the cosecant of the sun's altitude. Since the air masses for midday sunlight in summer remain fairly constant for a considerable period there will be only a gradual change of the ultraviolet intensity near its maximum value.

In winter, however, comparatively large variations in the midday air masses traversed by sunlight occur from day to day causing correspondingly large variations in the ultraviolet intensity.

The ozone content of the atmosphere decreases during the summer, which tends to displace the maximum noon intensity to a date later than 22nd December, the day when the solar altitude is greatest. The maximum noon intensity will occur when the effective thickness of ozone through which the sun's rays pass is at its lowest value. The effective thickness is given by—

$$d' = d.\text{cosec } \alpha$$

where α is the sun's altitude,

d is the vertical thickness of the ozone.

At Rietfontein the greatest noon intensity occurs about the beginning of January.

The ratio of midsummer to midwinter noon intensities for the Cd X cell is 2·5. For Cd Y it is 6·5, showing that the extreme solar ultraviolet is affected greatly by changes in the air mass. It may be pointed out here that the ratio of midsummer to midwinter noon values of the *total* solar radiation is only 1·1.

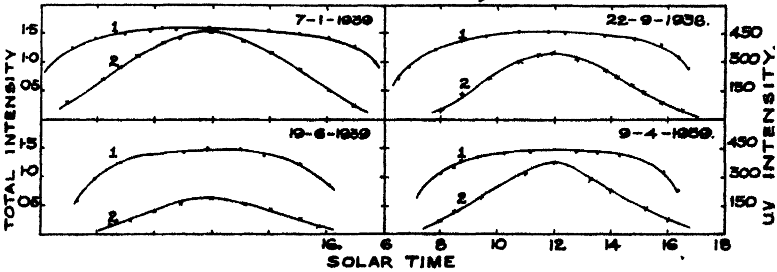

Fig. 11.

Showing the diurnal variations of the total and the ultraviolet solar radiations for days in the middle of each season.

(1) Total intensity in cals./sq. cm./min.

(2) Ultraviolet intensity in Davos units.

(d) *The Total Solar Radiation.*

On certain very clear days during some months readings of the total amount of sunlight received at normal incidence were taken with a calibrated actinometer of the bolometer type. Fig. 11 shows a comparison between the diurnal variations of the ultraviolet and the *total* solar energies for days in the middle of each season. The total amount is given in calories per sq. cm. per minute and rises very rapidly after sunrise, but is fairly constant for from five to six hours during the middle of the day. The ultraviolet intensity, on the other hand, increases slowly until the sun reaches an altitude of about 20° and then increases more rapidly but steadily until midday.

(e) *Atmospheric Absorption Coefficients.*

The atmospheric absorption coefficients for the ultraviolet were obtained using Bouguer's formula:—

$$\log I = \log I_0 - m.\sec z$$

where, m is the absorption coefficient.

I_0 is the intensity of the incident radiation outside the atmosphere.

I is the intensity of the same radiation when it reaches the cadmium cell.

Both intensities are taken in the same units when the sun is at zenith distance z.

If the absorption coefficient m is constant, the plot of log I against sec z (or air mass) will be a straight line. For individual days during which the ozone thickness remains unchanged, this condition will hold. Fig. 12 shows the lines obtained for days in midautumn and midspring. If these lines are extrapolated to zero air mass, then the difference between the values of log I at sec z = 0, and sec z = 1, will give the absorption coefficient,

$$\text{i.e., } m = \log I_0 - \log I$$

The coefficients obtained from the curves in Fig. 12 are respectively 0·61 and 0·52. The mean seasonal absorption coefficients obtained in the same way were:—

Winter (May-July)	0·59
Spring (August-October)	0·62
Summer (November-January)	0·57
Autumn (February-April)	0·54

The extrapolated lines in Fig. 12 meet at a point near zero air mass. The intensity in Davos units corresponding to no atmosphere from these lines is 1585, being 3·2 times as strong as the intensity at Rietfontein when the sun is directly overhead.

(f) *Effects of Atmospheric Ozone.*

If the noon ultraviolet intensities are plotted in the form of log I against sec z, the points produce a closed curve of

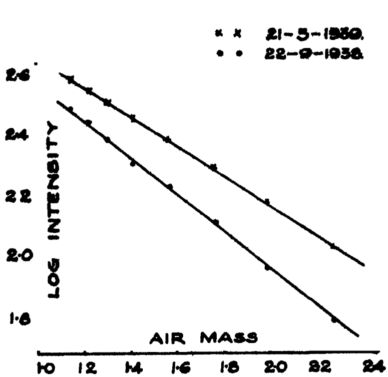

Fig. 12.

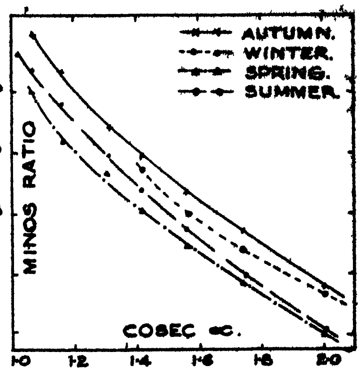

Fig. 14.

Fig. 12.—Showing the lines produced by plotting the equation:—
$\log I = \log I_0 - m.\sec z$
The points were obtained from cell readings on a day in midspring and one in midautumn.

Fig. 14.—Showing the seasonal means of the minos ratios for different air masses (cosec ∝).

elliptical shape. Throughout the spring the amount of ozone in the atmosphere is greater than the average amount for the year. This increase tends to lower the ultraviolet intensity to a value less than that which would normally be expected if the ozone layer maintained a constant thickness. The opposite effect is experienced in autumn when the amount of ozone is less than the average amount. Fig. 13a shows the closed curve for the Cd X cell readings. In Fig. 13b the points for rays unaffected by the ozone are plotted in a similar way. The intensities are those obtained when using the Cd X cell with the minos glass filter. These points do not form a closed curve, but are such that their mean values lie on a line approximately straight.

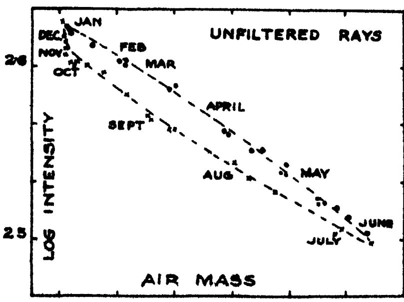

Fig. 13a.

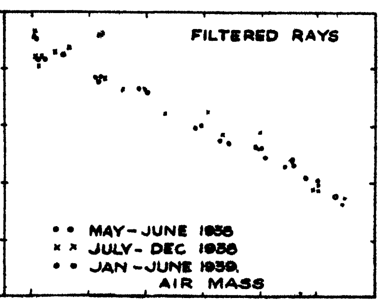

Fig. 13b.

Showing the points obtained by plotting log. ultraviolet intensity against air mass for noon values of the intensity of the direct sun's rays filtered by the minos glass, and of the unfiltered rays.

(g) *Variations in the Amount of Ozone.*

In order to obtain an estimate of the seasonal variation of the ozone thickness the method suggested by Götz was adopted (4). Götz found experimentally that the minos ratio is a continuous function of the length of path of the rays through the ozone. Thus, if two readings at different solar altitudes result in the same minos ratio, then the vertical thicknesses of the ozone layer at the times of these observations must be in the inverse ratio of the corresponding air masses. If the minos ratio is the same for two different sunlights, α' and α'', then the ratio of the corresponding vertical thicknesses of ozone is given by—

$$\frac{d'}{d''} = \frac{\operatorname{cosec} \alpha''}{\operatorname{cosec} \alpha'}$$

The monthly means of the minos ratios for different sun-heights were obtained from the daily graphs and plotted against air mass. These are given in Fig. 14.

Now, assuming the ozone thickness for the spring readings to be unity, the corresponding thicknesses for the other seasons were calculated using minos ratios of from 7 to 10. The mean summer, winter and autumn thicknesses on this scale were, respectively, 0·958, 0·908, and 0·872. These figures show a fairly small annual variation, as would be expected for a station of this latitude.

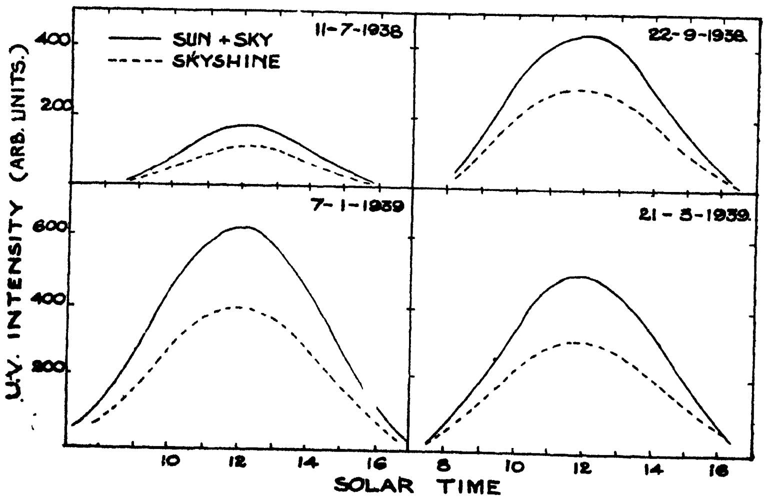

Fig. 15.

Showing the diurnal variations of the ultraviolet radiations received from sun plus sky and from sky alone for days in the middle of each season.

(h) *The Ultraviolet Skyshine.*

Besides measuring the total amount of ultraviolet received from the sun and sky by the ball type cell, the skyshine alone was obtained by shading the central sphere from the direct sun's rays with a small metal disc set normally to these rays and at a distance of 18 inches from the cell. This arrangement is shown in Fig. 6. Readings were taken, with and without the shade, on the same days that the other cells were used. From the results daily curves were drawn showing the variation of the ultraviolet in arbitrary units, from sun and sky together and from sky alone. Four of these curves are drawn in Fig. 15, each one taken on a day in the middle of a season of the year.

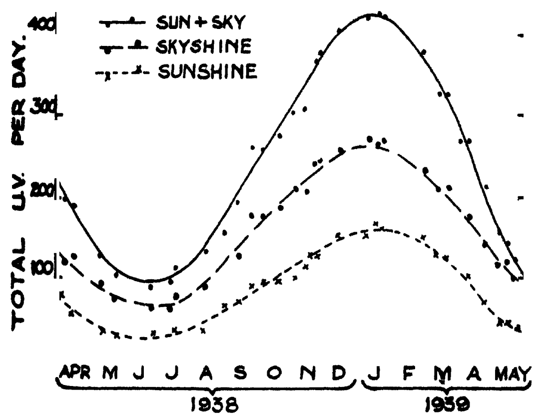

Fig. 16.

Showing the annual variation of the total daily amounts of ultraviolet radiation received from the sun and sky separately and from the two together.

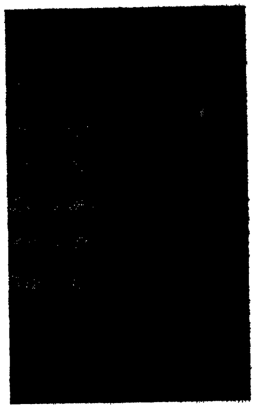

Fig. 19.

A positive print showing ten solar spectra taken at different times during a day together with two iron arc spectra.

The daily observations indicate that early in the morning the percentage ultraviolet skyshine to total sun and sky radiation varies between 70 and 80, decreasing to about 60 per cent. at midday. At no time throughout the year is the skyshine less than 50 per cent. of the total amount received by the cell from sun and sky together.

By taking the areas under the daily curves, the total ultraviolet intensity received for the *whole day* from sun plus sky or from sky alone can be calculated. The difference between these two amounts will, of course, give the total amount of ultraviolet received for the day from the sun alone. These calculations were made only for one or two clear days each month. Fig. 16 shows the points obtained in this way.

The total ultraviolet received from both sun and sky during a day in summer is about five times as much as that received from the same sources on a day in midwinter. The corresponding ratios for skyshine and sunshine alone are:—

Skyshine	4·5
Sunshine	5·7

In addition, the total daily ultraviolet skyshine during the winter months is just more than twice that of the sunshine. In summer it is about 1·7 times as much.

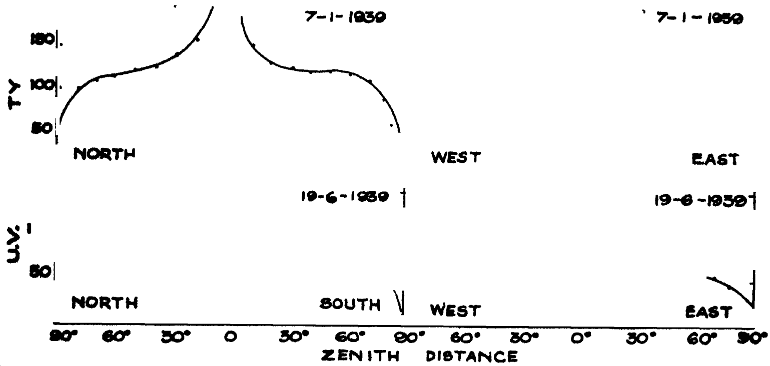

Fig. 17.

Showing the distribution of the ultraviolet (in arbitrary units) over the sky for days in summer and winter.

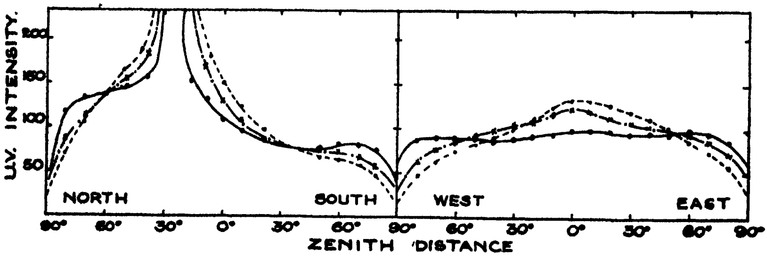

Fig. 18.

Showing the effects of haze on the distribution of the ultraviolet over the sky.

———— 21/9/'38—Very clear.
— . — . 22/9/'38—Hazy.
- - - - - 26/9/'38—Very hazy.

(i) *Distribution of the Ultraviolet over the Sky.*

Next, the distribution of the scattered ultraviolet over the sky was determined. This was done by using the Cd X cell with an aperture half full size. The intensities were measured for every 10° elevation, from the western horizon across the sky to the eastern horizon, and similarly from the northern to the

southern horizons, about midday on very clear days. The plots of these in arbitrary units for days in summer and winter are given in Fig. 17. From these curves the ultraviolet is seen to be very evenly scattered over the major portion of the sky, but fades rapidly towards the horizon. The shapes of the distribution curves, both for north to south and for east to west, remain the same throughout the year, but the ordinates increase for greater solar altitudes.

On cloudless but hazy days the shapes of the curves change. An increased amount of scattering occurs immediately around the sun, but near the horizon the amount of light scattered is far less than would be expected for a clear day. Thus on hazy days the greater portion of ultraviolet skyshine originates near the central area of the sky. The haze above Rietfontein consisted of moisture, which later formed into clouds, and smoke from the Rand industrial area. Fig. 18 shows the effect of various amounts of haze on the distribution of the ultraviolet skyshine. The readings were taken on three days during one week. One day the air was very clear, on another there was a slight haze, but on the third day it was very hazy.

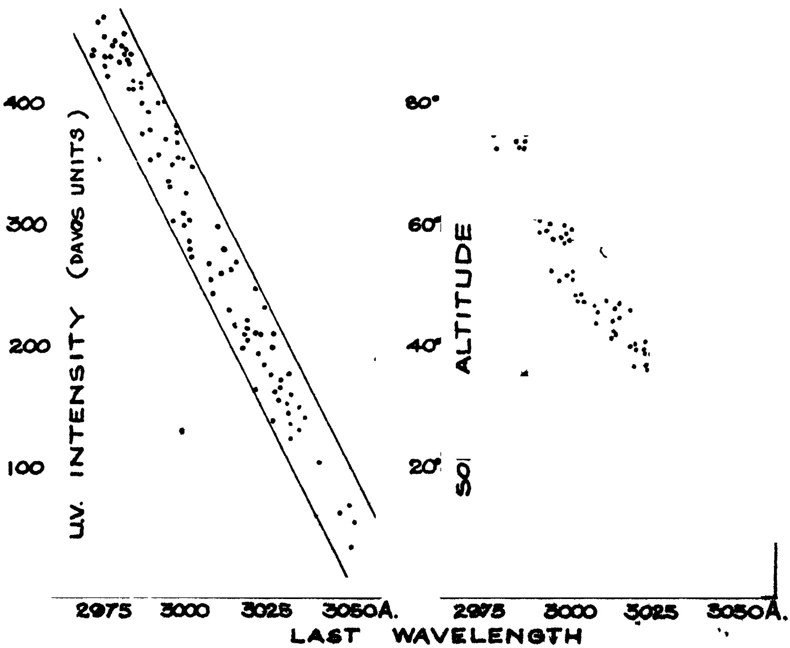

Fig. 20. Fig. 21.

Fig. 20.—Showing the relation between the ultraviolet intensity and the last wavelength of the sun's spectrum.

Fig. 21.—Showing the relation between the solar altitude and the last wavelength of the sun's spectrum.

(j) *The Last Wave-length in the Sun's Spectrum.*

On the days that the cells were used during the last six months, spectrograms of the sun were taken using a small quartz solar spectrograph with the object of determining the last wave-length in the sun's spectrum. The instrument contains a gold film which absorbs the major portion of the visible light. Agfa Isochrom films were used, ten exposures each of two seconds duration being made on each. These films were then developed in a solution at 18° C. made from "Tabloid" brand Rytol developer in distilled water. Fig. 19 shows a positive print of one of the films.

A few lines in the solar spectrum were identified by making exposures of the copper and iron arcs on some of the films. The last wave-length was taken as the last observable line of darkening on the film. A travelling microscope was used to measure the distances of the last dark lines from a line of known wave-length. The distances were later checked to ensure that a standard of observation was kept throughout.

The results were plotted against ultraviolet intensity in Davos units and sunheight. Fig. 20 shows the plot of the last wave-length against the ultraviolet intensity. All the points fall within a band bordered by two parallel straight lines which cut the X axis at two points 18 angstroms apart. The points show that the greatest intensities are accompanied by the shortest wave-lengths and that the intensity is zero if the last wave-length is greater than 3075A.

In Fig. 21 the last wave-lengths are plotted for different sunheights. From this it is seen that for a given solar altitude the last wave-length has a definite value ± 10 angstroms.

The least value of all the readings occurred at 2973A at midday in midsummer. The least midday value in midwinter was 3025A.

The effect of a very thick smoke haze on the 14th June was to absorb all wave-lengths below 3100A at 8.30 a.m. and 3090A at 2.30 p.m. From the curve of the mean points in Fig. 21 these values would read 3060A and 3040A, respectively, for the times stated. A thick haze is therefore responsible for shortening the sun's spectrum by about 50A at the ultraviolet end.

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I wish to express my appreciation of the valuable help and advice given me by both Prof. H. H. Paine and Miss G. Reimerschmid. I wish also to thank the Union Public Health Department for the use of the apparatus, and the Director of the Minerals Research Laboratory, University of the Witwatersrand, for the use of a monochromator.

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THE SPLITTING OF THE ATOM

BY

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Read July, 1939.

South African Journal of Science, *Vol. XXXVI, pp. 150-154, December, 1939.*

DIE REFLEKSIEVERMOË VAN VERSKILLENDE REFLEKTORS SOOS IN PADSEINE GEBRUIK

DEUR

D. Fourie,

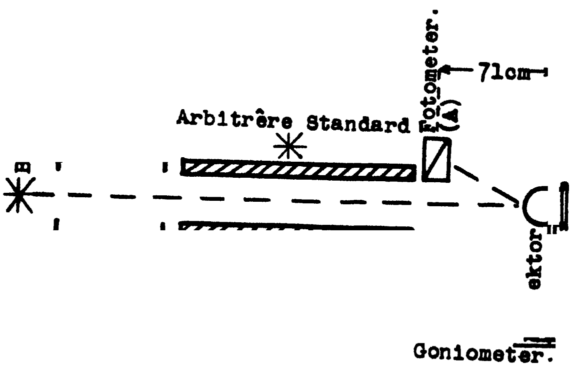
Universiteit van Pretoria.

Met 3 Teksfigure.

Gelees 5 Julie, 1939.

Die doel van hierdie ondersoek is om te bepaal hoeveel lig weerkaats word van reflektors wanneer die invalshoek verander.

Dit is heel duidelik dat 'n reflektor wat maksimale weerkaatsing gee binne 'n beperkte hoek, nie doeltreffend sal wees nie omdat die hoek met die naderende moter verander na gelang van sy afstand van die sein. Dus sal die bestuurder net gewaar word van die "gevaarsein" op 'n bepaalde afstand en vir 'n betreklike kort tyd, waarna die sein weer duister sal wees.



Indien die refleksievermoë meer dan een maksimum gee vir toenemende invalshoeke, sal die bestuurder op meer dan een plek die sein duidelik sien—dit is vanselfsprekend dat die hoek tussen die sein en die bestuurder na gelang van sy afstand van die sein verander, daar die sein nie in die middel van die pad kan staan nie. Ten einde die refleksievermoë vir verskillende invalshoeke te bepaal, was die apparaat opgerig soos in Fig. 1 aangedui is. In plaas van die bron te verskuif, soos die geval met 'n moter sal wees, is die bron vasgehou en die invalshoek op die sein verander. Hierdie verandering is afgelees op die goniometer waarop die sein gemonteer is.

Eerstens was die " knopies " geplaas vir loodregte invalshoeke en die intensiteit van die weerkaatste straal is bepaal deur die Fotometer A, deur 'n konstante sekondêre bron te gebruik.

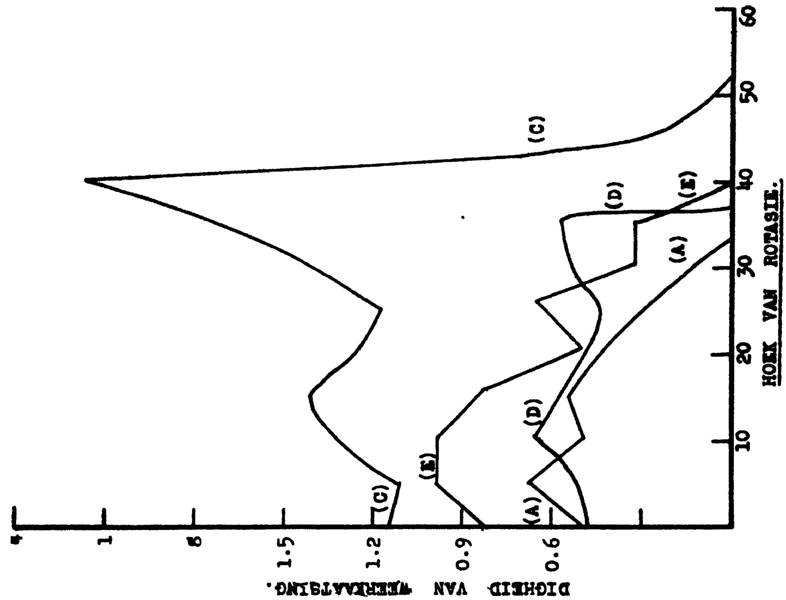
Die bogenoemde " knopies " bestaan, as een soliede kombinasie, uit een of meer glas-silinders met verskillende deursnedes, met die voorkant bolvorming en die agterkant hol of bol en met weerkaatsende verf bestryk of van 'n poleerde metaal-reflektor voorsien. Die hele kombinasie vorm dan 'n lenssisteem met 'n reflektor agter.

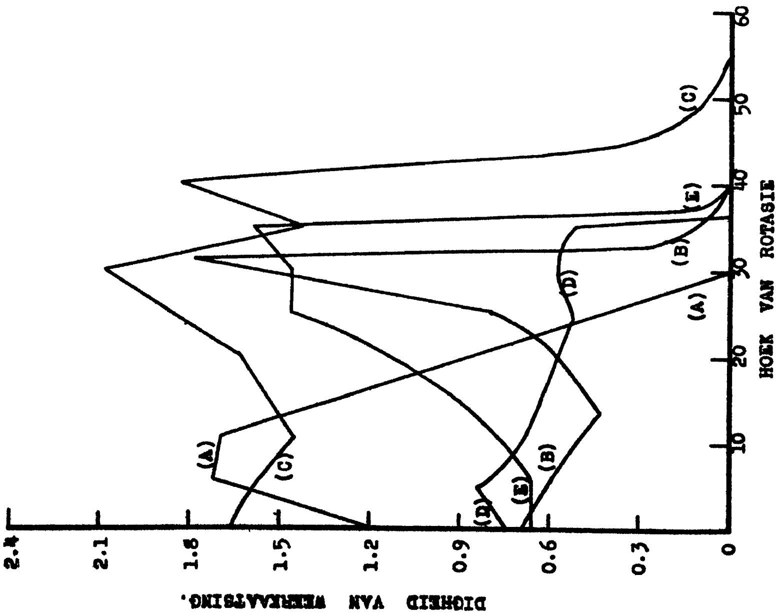
Die verhouding van 'n paar tipiese " knopies " is aangedui in Fig. 2. Hierdie krommes dui duidelik aan dat sommige " knopies " se refleksievermoë binne 'n baie beperkte hoek lê, sien (B)—dit beteken dat die sein skielik sal opblits en uitdoof wanneer die moter op 'n bepaalde afstand is, terwyl ander " knopies " 'n maksimum gee wat langsamerhand uitdoof en weer tot 'n maksimum, dus 'n tweede waarskuwing styg. (A) gee 'n groot refleksievermoë van 5—10° en is by 30° uitgedoof, terwyl (B) 'n swak refleksievermoeë het, tot 'n maksimum styg by 30° en dan snel afval tot ongeveer niks by 33°. (C) se refleksie word wel verswak op 10°, maar vandaar styg dit na 'n maksimum by 30°, sak tot 'n kleinere minimum by 35° styg weer tot 'n maksimum by 40° en is skynbaar eers uitgedoof by 47°. Hieruit kan ons aflei dat (B) nie goed sigbaar sal wees nie, wanneer die moter op 'n lang afstand is, en net 'n skielike blits op 32° sal gee. terwyl (A) op 'n langer afstand 'n waarskuwing sal gee, natuurlik met 'n swakker intensiteit daar die kar dan verder is, maar wanner die kar nader, is sy uitgedoof; B kaats dan egter skerp terug. Aan die ander kant gee C 'n taamlike weerkaatsing tot op 40° waar dit dan eers begin uitdoof—d.i. C is meer doeltreffend dan A of B. Vir 'n sterk lig sal D 'n keuse wees na C.

Van 'n praktiese oogpunt moet ook in aanmerking geneem word dat hierdie " knopies " aan wind en weer blootgestel is en dus sal die kwarts deeltjies wat die wind teen hulle waai, die oppervlakte mat maak en die refleksie vermoë vermoedelik beinvloed.

Teneinde die effek hiervan te ondersoek was elke " knopie " onderwerp aan 'n kunsmatige dog standardiseerde " sandstorm," wat nageboots was deur 'n " Pheune " te gebruik om 'n konstante stroom fvn kwartsand onder dieselfde kondisies teen die " knopies " te blaas. Na hierdie behandeling is die " knopies " weer ondersoek soos bogemeld en die bevindinge is voorgestel in Fig. 3.

Dit blyk dat (C) weinig beinvloed is deur hierdie behandeling—tot by 35° is die intensiteit verswak, terwyl die maksimum by 40°, gestyg het. (E) se intensiteit het tot by 15° gestyg dog is dan heeltemal verswak—hierdie " knopie " word gevolglik erg beskadig deur die sand. Dieselfde verswakking is by (A) op te merk, terwyl (D) feitlik onveranderd bly.


HOEK VAN ROTASIE.
DIGHEID VAN WEERKAATSING.
(A)
(C)
(D)
(E)


HOEK VAN ROTASIE
DIGHEID VAN WEERKAATSING.
(A)
(B)
(C)
(D)
(E)

Die toename in intensiteit by sekere hoeke, na die "sandstorm" is waarskynlik te wyte aan die terugkaatsing van die uittredende strale vanaf die voorste mat oppervlak van die "knopie," en deur 'n tweede weerkaatsing van die versilwerde agtervlak, gaan hierdie strale in die rigting van die invallende strale—gevolglik 'n konsentrasie van die weerkaatsing in daardie rigting.

In die praktyk word die "seine," langs die paaie, waargeneem deur die blote oog van die bestuurder van die moter. Om die sigbaarheid van "seine" soas letters vas te stel, sal dit tot valse gevolgtrekkings lei as 'n kamera vir waarneming gebruik word, want hier het ons te doen met die ontbindingsvermoë van die menslike oog en nie van 'n enkel lens waarvan die openingsverhouding vas is nie.

Ten einde die sigbaarheid te bepaal, was die "knopies" in verstelbare houers op 'n draaibare stander aangebring. Persone wat bo 'n skerp moterlig op 150 tree afstand, die refleksie waargeneem het, terwyl die "knopies" gedraai word—d.w.s. die invalshoek verander word—het die maksimum refleksie presies op die hoeke wat deur die krommes in Fig. 2 aangegee was, waargeneem.

Om te ondersoek op welke afstand die "knopies" van mekaar geplaas moet word op hierdie afstand, sodat letters in die "sein" vir die bestuurder van 'n moter leesbaar sal wees, moet die ontbindingsvermoë van die menslike oog op daardie afstand vasgestel word. Vir hierdie doel is die "knopies," by maksimum weerkaatsing, uitmekaar geskuif totdat die waarnemer bo die motorlig, hulle net van mekaar kan onderskei. Hierdie afstande gee dus die minimum afstand tussen die "knopies" sodat die "sein" sigbaar sal wees, sonder 'n blindende effek daarby, wat die letters onleesbaar maak. Die afstand, vir "knopies" gemerk (C) was 7 c.m., en vir die gemerk (A) was dit 3·5 c.m.

Dit is duidelik dat die hoogte van die "sein" bo die padoppervlak, 'n groot rol speel in die sigbaarheid van die "sein." Vir swak ligte of neergeslane ligte sal 'n hoë sein nie genoeg belig word om 'n duidelike refleksie te gee nie, terwyl 'n lae sein weer geen refleksie sal gee in die rigting van die bestuurder van die moter nie. Die hoogte sal natuurlik afhang van die afstand waarop die sein sigbaar moet wees—vir lang afstande sal 'n taamlike hoë sein doeltreffend wees, aangesien dit dan helder bo die oppervlak afwys en ook deur neergeslane ligte belig kan word. Hoe korter die afstand word des te laer sal die "sein" moet wees en die minimum hoogte sal effens hoër as die moterlig wees, aangesien al die reflektors maksimum of toenemende refleksie gee met 'n invalshoek van 0—10°.

Ten slotte wens ek my dank te betuig aan Mnr. Shannon, hooftegniese adviseur van die Nasionale Padraad, en Prof. J. S.

van der Lingen, hoof van die Departement van Fisika, vir sy belangstelling en goedgunstige toestemming vir die gebruik van ruimte en privaat apparaat.

ENGLISH ABSTRACT OF PAPER.

The reflection of various reflector-buttons used in road signs, was measured as seen by a person above the source of incident light. The graphs in the paper show clearly that the intensity of reflection varies with the angle of incidence—this variation is of great importance in motor traffic.

The effect of sandstorms on the buttons is shown in a second series of curves. From these graphs it is easily seen which buttons can endure the treatment to which they are subject on the roads.

DISCHARGE LAMPS

BY

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Read July, 1939.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVI, pp. 155-157*
December, 1939.

THE SPECIFIC GRAVITIES OF CLAYS

BY

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Read 3 July, 1939.

For the evaluation of the particle-size of that fraction of a clay less than 43μ (the aperture of finest standard sieve available), it is necessary to determine the specific gravity.

During the course of size-analysis on some refractory, semi-refractory and non-refractory clays, numerous specific gravity determinations were made, and some interesting results obtained. From Table 1 it will be seen that the specific gravities for the various clay minerals are in some cases very different. These values are quoted from current mineralogical textbooks. (Dana, 1932.) It will be noticed that it should be possible to differentiate between a kaolinite and halloysite bearing clay (i.e. clays with very similar chemical composition). However, from the results given in this paper it will be obvious that the liquid used may have a considerable effect on the specific gravity determination, and the medium should therefore be specified.

The bottle used has a volume of about 50 ccs. and is fitted with a stopper through which a 1/10°C. thermometer projects. All operations were carried out at a fairly constant temperature, the range never being allowed to fluctuate more than 1°C. In most cases the temperature was kept far more constant than this. The sample and liquid were subjected to evacuation and not to boiling to remove bubbles.

In Table 2 the specific gravities of some clays from the Eastern Province are given. It will be noted that only in the case of some of the highly ferruginous clays (the lateritic types) are there marked differences between the values in water, carbon tetrachloride and alcohol. The white residual clays behave rather erratically; sometimes consistent results are obtained in various liquids and at others fairly large deviations are noticed. It is worth while mentioning that the consistently high specific gravity (2·71) for some of the clays, is inexplicable at present. These clays consist mainly of quartz, crystalline kaolinite and colloidal kaolinite. The amount of heavy minerals, i.e. rutile, limonite or magnetite, is very small.

In Table 3 the values for refractory and other clays of the Witwatersrand area are shown, the determinations having been all made in carbon tetrachloride. It was hoped to be able

to distinguish between halloysitic and kaolinitic clays, but constant values *in the same liquid* could not always be obtained. It is appreciated, of course, that a clay is a heterogeneous aggregate and that it may contain in varying quantities the minerals given in Table 4. Detailed chemical and physical analyses had been completed for the great majority of these specimens, so that the importance of their accessory minerals was known. The main accessory mineral in practically every clay examined is quartz, which has a specific gravity little different from that of kaolinite.

The determination of specific gravity by the method used is liable to two errors, one being adsorption of the liquid by colloidal particles and the other the slow or non-penetration of the liquid into pores almost approaching molecular dimensions. In the clays examined the accessory minerals, i.e. quartz, haematite, magnetite, ilmenite, hydromuscovite, feldspar, etc., were in general of little importance. Limonite is considered a clay mineral, as it can be slaked and dispersed, when not admixed with a great deal of " inert " matter.

Recently the importance of organic colloids in clays has been realised. Usually the quantities are small, but in the case of the fireclays and black turfs may amount to 4-5 per cent. The chocolate fireclays in the Witwatersrand area are extremely important from the economic point of view. Any work that can increase our knowledge of their constitution is important. To neglect the organic fraction therefore, and simply to include in the loss on ignition carbon, hydrogen and oxygen, which actually belong to organic phases, is wrong. The bulk specific gravity of the organic minerals is probably about 1·0, but so far attempts to isolate them have been unsuccessful. The intimate association of organic and inorganic colloids necessitates some process such as electro-dialysis.

Another method of approach to the determination of specific gravity is by X-ray diffraction. (Davey, 1934.) So far this method has only been applied to single phases and the difficulties in the case of a heterogeneous system such as clay, are at present very great.

TABLE 1.

Mineral.	Specific Gravity.
Kaolinite, Dickite, Nacrite	2·6 –2·63
Halloysite	2·0 –2·20
Anauxite	2·542
Beidellite	2·6
Montmorillonite	2·0
Pyrophyllite	2·8 –2·9
Nontronite	1·727–1·870
Allophane	1·85 –1·89

TABLE 2.

Clay Type.		Specific Gravity in CCl_4	in C_2H_5OH	in H_2O
Blue-green marine clay	...	2·64	—	2·65
Red Marine clay ...	...	2·53	—	2·54
Ferruginous laterite	...	2·60	2·59	2·14
White residual clay	...	2·67	2·67	2·61
White residual clay	...	2·77	2·72	2·54
White residual clay	..	2·71	2·77	2·70

TABLE 3.

Clay Type.	Specific Gravity.
Yellow shale clay ...	2·66–2·71
Carbonaceous shale clay	1·87
Plastic fireclay ...	3·04
Non-plastic fireclay	3·38
Non-plastic fireclay	2·63–2·74
White fireclay ...	2·15–2·50
Non-plastic fireclay	2·47
Flint clay ...	2·66
Plastic fireclay ...	2·57
Blue coloured fireclay	2·45
Plastic siliceous fireclay	2·52
Plastic fireclay ...	2·52
White non-plastic fireclay ...	2·35
Argillaceous sandstone	2·42

TABLE 4.

Accessory minerals in clays.

Mineral.	Specific Gravity.
Quartz ...	2·65
Orthoclase feldspar	2·56–2·58
Microcline	2·54–2·57
Plagioclase feldspar	2·60–2·75
Ilmenite ...	4·5 –5·0
Rutile ...	4·18–4·25
Limonite ...	3·6 –4·0
Hydro-micas	2·76–3·0
Haematite	4·9 –5·3

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South African Journal of Science, *Vol. XXXVI, pp. 158-163, December, 1939.*

ATMOSPHERIC AMMONIA AS THE PRIMARY SOURCE OF NITROGEN TO PLANTS

BY

G. Ingham.

Read 4 July, 1939.

One of the earliest problems confronting the pioneers of Agricultural Science a century ago, was the determination of the source from which plants derived the hydrogen, oxygen, carbon and nitrogen of which 99 per cent. of their substance was composed. Hydrogen and oxygen were obviously supplied by the water originally present in the air as aqueous vapour, precipitated as rain and reaching the plant through the roots. After much controversy in which Liebig played a prominent part, it was generally accepted that carbon was obtained entirely from the carbonic acid of the air, although it was well-known that the soil may contain 100 times more carbon in the form of organic matter than is present in the atmosphere.

There remained the question of nitrogen and Liebig affirmed that this, too, came from the air as ammonia which was taken up by the roots of plants from its solution in rain water.

A few years later, however, Lawes and Gilbert of Rothamsted showed that rain water brought down only about 4 lb. of nitrogen compounds per acre per annum and they drew the conclusion that the amount of ammonia obtainable from the atmosphere was therefore insufficient for the needs of a crop. They also asserted that such nitrogenous compounds as ammonia and nitrate were necessary for plant growth and that these nitrogenous compounds came from the reserves of organic matter in the soil. This did not solve the problem of the original source of plant nitrogen, for it is obviously only shifting the problem a stage further back to say that the nitrogen of plants is obtained from the residues of pre-existing plants.

Nitrogen is lost from the soil in the drainage water as nitrates and is also removed by the crop. These two sources of loss will generally amount approximately to 100 lbs. of nitrogen per acre per annum. As an average soil contains only 0·1 per cent. of nitrogen, i.e., 2,000 lbs. calculated to a depth of six inches, the reserves of nitrogen would generally be exhausted in 20 years if there were no other source of supply.

According to existing theories of nitrogen fixation, the abovementioned losses are made good by the activities of nitrogen-fixing bacteria.

S. A. Waksman (1931) in his work on Soil Microbiology after referring to the small amount of combined nitrogen brought down

by the rain, concludes with the words: " The rest of the nitrogen is presumably fixed in the soil by the agency of micro-organisms." Thus after 100 years the latest theory on the subject amounts to nothing more than the vague statement that the greater part of the nitrogen required by plants is " presumably " fixed in the soil by micro-organisms.

A little consideration will show, however, that this presumption is a large one.

There are two main classes of organisms concerned in nitrogen fixation. (1) The bacteria found in nodules on the roots of leguminous plants and (2) the free-living bacteria such as Azotobacter chroococcum and Clostridium pasteurianum.

With reference to the first of these classes it is undoubtedly true as Hellriegel and Willfarth showed in 1888 that legumes, on whose roots these nodules were found, were able actually to increase the total nitrogen in the soil, and this was ascribed to a fixation of the elementary nitrogen of the air.

The amount so fixed is, however, a highly debatable question as it depends partly on the specific bacterial strain and partly on the amount of nitrogen already present in the soil, so that estimates by different authorities put the amount fixed, at anything from 0 to 100 lbs. per acre per annum, while under certain conditions the organisms become parasitic on the plant and fix no nitrogen at all.

Granting however that these bacteria may be a factor in replenishing the losses of nitrogen, it is obvious that such beneficent action can only apply to land where leguminous plants are actually growing and this in the Union of South Africa is not more than 0·45 per cent. of the 200 million acres of total farm land. The remaining 99·55 per cent. is still subject to leaching by rain and to crop removal but is unfortunately beyond the reach of bacteria so beneficent.

There remains, however, the second class of free-living bacteria already mentioned. In 1901 Beijerinck discovered Azotobacter chroococcum, which under highly artificial conditions in a culture solution at optimum temperature and supplied with sugar, mannitol or similar carbohydrate, was able to fix at the utmost 10 milligrams of nitrogen for each gram of carbohydrate consumed. Assuming (a large assumption) that it could do the same in an ordinary agricultural soil it would need at least 5 tons of sugar to enable it to fix 100 lbs. of nitrogen, i.e. it would be necessary to plough into the soil a 50 ton green manure crop of sugar cane, or assuming (a still larger assumption) that cellulose is just as good as sugar, an ordinary green manure crop of 25 to 50 tons would be required to supply the necessary energy-producing material and this would have to be repeated annually.

A consideration of the facts given above, leads to only one conclusion, viz., that current theories regarding the restoration of nitrogen to the soil, are entirely inadequate and that the

fixation of nitrogen by micro-organisms other than legume bacteria, is of little more than academical interest.

There is, however, a perfectly simple explanation of the fact that a soil may lose 100 lbs. of nitrogen per acre annually, without drawing upon the reserves of organic matter to any considerable extent.

According to this theory a soil, and especially a well-tilled soil, is able to absorb from the air in 12 months sufficient nitrogen in the form of ammonia to supply the needs of a crop like maize. The existence of ammonia in the air is beyond question. It was known to Liebig 100 years ago and numerous analyses of rain water in all parts of the world, show that it contains both ammonia and nitrate. Monthly determinations extending over four years in Natal gave an average of 5 lbs. per acre per annum, which is of course only a fraction of the total nitrogen required by a crop. There is the possibility however, that ammonia may be absorbed by the soil directly from the air. The actual ammonia content of air is very small. The mean of a series of 70 determinations of atmospheric ammonia made by the writer in Natal, gives a figure of 1·3 milligrams of ammonia nitrogen per 1,000 litres of air or roughly 1 part per million by weight. This seems almost negligible but it may be pointed out that the carbon content of the air is only 100 parts per million and the requirement of plants for carbon is from 50 to 100 times their requirement for nitrogen.

As regards the absorption of ammonia from the air it is easy to show that any absorbing surface at the ground level will take up an appreciable amount of ammonia in a comparatively short time. Take for instance a glass dish containing slightly acidulated water. An exposure for a period of even three days in the open is quite sufficient for demonstrating the presence of ammonia which can not only be readily detected by nesslerising but can be even measured with a fair degree of accuracy. Such determinations at different intervals and with absorbing surfaces of different areas show that the amount of ammonia absorbed is proportional to the area exposed and is also proportional to the time.

An example showing the actual amount of ammonia absorbed in seven days is given below:

Area of Surface.		Ammonia Nitrogen Absorbed.
66·5 sq. in.	...	0·57 mgrms.
22·5 sq. in.	...	0·23 mgrms.

Another absorbent which may be used is china clay, for Faraday (1825) showed that a surface of china clay which had been first ignited and then exposed to air, took up an appreciable amount of ammonia in a week. This experiment so significant to agriculturists, appears to have been completely ignored. The transition from china clay to a soil containing clay and other

colloids is but a step and following up this experiment of Faraday's, the writer exposed a quantity of soil in a tray 3 inches deep to air in the open, watered it from time to time with ammonia-free distilled water and when partially dry, reduced it to a fine state of tilth. Absorption of ammonia took place as in the previous experiments but the quantity absorbed was much greater. It has been pointed out that absorption is proportional to the area of surface exposed and in a well-tilled soil the surface exposed is the sum of all the surfaces of the individual particles and is therefore enormously greater than the nominal soil area. The amount actually absorbed at monthly intervals is shown in the following table:

Period (Months).	Total Nitrogen. %	Ammonia Nitrogen. p.p.m.	Nitrate Nitrogen. p.p.m.	Organic Nitrogen. %
0	0·308	15	0·7	0·307
1	0·315	54	11	0·308
2	0·321	97	12	0·309
3	0·318	157	23	0·301
4	0·322	172	23	0·303
5	0·330	234	29	0·304
6	0·339	280	30	0·308
18	0·350	418	30	0·305

Thus at the end of 18 months ammonia nitrogen to the amount of 418 parts per million of soil has been absorbed.

It may be objected that as the soil was not sterilised, the observed increase of nitrogen may be due to fixation by Azotobacter. This is however, out of the question as the Azotobacter organism is inactive below a pH value of 6·0 and the pH value of the above soil was 5·1. Moreover nitrogen fixation is an endothermic process requiring the expenditure of energy which in this case could only be derived from the oxidation of the organic matter in the soil. This soil contained 8 per cent. of organic matter at the beginning of the experiment and if nitrogen fixation by bacteria had taken place, half of this organic matter would have disappeared, assuming that the carbohydrates oxidised were equal to 100 times the quantity of nitrogen fixed.

A determination of the carbon content of the soil, however, at the beginning and the end of the experiment, showed a loss of only 0·2 per cent. of organic matter.

The object of the above experiment was to show not only that ammonia can be absorbed from the air by soil but that under suitable conditions it may be absorbed in sufficient quantity to make good what is lost in the drainage water or removed by the crop. On reference to the table given, it will be seen that even in six months 280 parts of nitrogen per million of soil has been absorbed which, calculated to a depth of three inches, is equal to 280 lbs. per acre or three times what a good crop of maize would require.

The seat of absorption is evidently the colloidal complex which includes both organic colloids (humus) and inorganic colloids as clay. Of these the organic colloids have the greatest absorbing power for ammonia and other bases, while the absorptive capacity of the inorganic colloids of clay appears to be directly proportional to the ratio of silica to sesquioxides of iron and aluminium (Russell, 1927).

The theory of the replenishment of the soil by ammonia from the air, affords a ready explanation of the advantages of fallowing. A classical example of this is recorded in the annual reports of Rothamsted (1934), where a field which had been cropped with wheat for 100 years without manure or fertiliser and was giving a much diminished crop, viz., 3 or 4 bags per acre, was completely restored for the time being by a year's fallowing, so that the crop after fallow amounted to 10 bags per acre, slightly exceeding that of a corresponding plot which had received annual applications of 14 tons of farmyard manure per acre for the whole period. Moreover this soil had lost in the last 50 years only 0·01 per cent. of its original stock of nitrogen (Russell 1927).

At a meeting of the British Association for the Advancement of Science 41 years ago, Sir W. Crookes alarmed the scientific world by drawing attention to the dwindling supplies of Chile saltpetre and predicting that unless a practical method of nitrogen fixation were soon discovered "the great Caucasian race would cease to be foremost in the world and would be squeezed out of existence by races to whom wheaten bread was not the staff of life."

It is doubtful, however, whether there was ever any immediate danger of a shortage of fixed nitrogen for the growth of wheat, because the ultimate source of combined nitrogen for plants, as shown above, is in the ammonia of the air—not in the nitrate deposits of Chile. The actual amount of ammonia present in the atmosphere has been estimated at 5,100 million tons and this is probably maintained at a fairly constant level by accessions from the ammonia which escapes into the air when sea water evaporates. Ammonia occurs in the sea water of all latitudes (0·25 grm. per 1,000 litres in the Indian Ocean off the Natal coast) and as the pH value of sea water is approximately 8·3, ammonia is given off with water vapour when evaporation takes place. The fixation of nitrogen has, however, been successfully achieved on a large scale and although the problem was not as urgent or as vital in regard to agriculture as Crookes supposed, the supplies of combined nitrogen thus created are of great value in supplementing those which occur naturally in the air and soil. As a fertiliser it is of value by enabling the farmer to produce larger crops on a smaller area or to obtain two crops per annum from land which would otherwise need fallowing for a year or two to give the same result. Moreover the high yielding crops which botanical selection has made possible, are more exacting in their requirement of nitrogen than primitive vegetation, and

pastures consisting of improved strains of grass respond handsomely to applications of nitrogen fertilisers while they would yield only meagre crops if dependent on the natural supplies of nitrogen in the soil.

Summary.

It has been shown that current theories regarding the restoration of nitrogen to the soil by nitrogen-fixing bacteria, are entirely inadequate.

The theory put forward in this paper is a modification of Liebig's original theory that ammonia is derived from the air, and asserts that not only is ammonia brought down by the rain, but that it is also directly absorbed from the air by the organic and inorganic colloids in the surface soil.

This theory supplies a reasonable explanation of the fact that a soil may lose annually 100 lbs. of nitrogen per acre in drainage and by crop removal, without suffering a corresponding loss of organic matter.

The theory also shows why fallowing has substantially the same effect on crop production as an application of a nitrogenous fertiliser.

Acknowledgment.

The writer wishes to express his thanks to Messrs. African Explosives and Industries, Ltd., for the facilities afforded by their laboratories at Umbogintwini, Natal, for carrying out the above work.

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South African Journal of Science, *Vol. XXXVI, pp. 164-169, December, 1939.*

PEBBLE BEDS IN THE LOWER BEAUFORT SERIES OF THE EAST LONDON DIVISION

BY

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With 1 Text Figure.

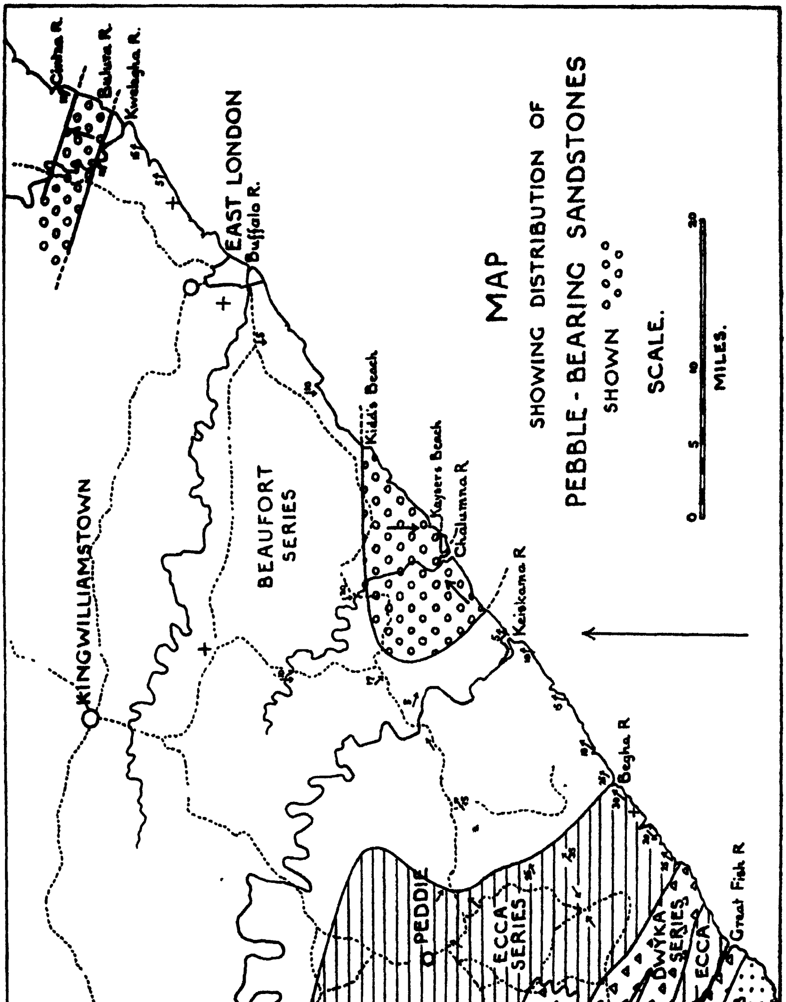
Read 4 July, 1939.

A few years ago I collected a large number of pebbles from the outcrop of Lower Beaufort sandstone in the bed of the Kwelegha River, where the latter is crossed by the main Transkei road from East London. At this locality the beds, which dip N. 18° E. at an angle of about 10°, are buff-coloured, false-bedded, and in places calcareous, sandstones with abundant concretions showing concentric colour-banding, and occasional veins and fibrous concretions of calcite. The pebbles vary up to 3 inches in size and are mostly well-rounded without any characteristic shape. They occur scattered throughout the sandstone, but tend to be concentrated in definite layers. Just below the crossing the pebbles are seen to be distributed in a krantz through a vertical thickness of some 150 feet.

One exceptionally large pebble, more than 4 inches in size, consists of silicified wood, while another conspicuous pebble about 2 inches across consists of a handsome porphyry with flesh-coloured feldspar phenocrysts up to 0·4 inch in diameter. The pebbles collected comprise the following materials, roughly in order of diminishing frequency of occurrence: white and grey quartzite, purplish quartzite, silicified wood, greenish grits and greywacke, pink to grey porphyry and felsite, arkose, red granite, chert and jasper, pink gneiss, grey gneiss, and pale-yellowish sandstone. In addition, pebbles of argillaceous material and of chloritic vein-quartz were collected, and one small pebble of graphic granite. The red colour of many of the igneous rocks is a conspicuous feature.

The same horizon is readily recognisable along the coast about 3 miles south of the Cintza River mouth. The rock is again a buff or creamy false-bedded sandstone with planes of false-bedding generally dipping inland, and is overlain to the north by sediments showing a remarkable development of concretionary structures rendered conspicuous by marine erosion. These overlying sediments, however, contain no pebbles. On the

other hand, the pebble-bearing sediments were found to continue south to a point just beyond the Bulura River mouth, a total distance of some 2½ miles.



Here the nature of the pebbles is very much the same, only that there appears to be a somewhat greater range of types. The quartzites, for instance, are sometimes black and very glassy, while the granites include a few specimens of a rather fine-grained white muscovite-granite, although the granites are still predominantly reddish. Among the sandstones, too, are a few

pebbles of a white chalky-looking rock which is fine-grained and shows no bedding. Cherty rocks are common, some replacing wood, but others, of a variety of reds, browns and greens, showing no such texture. One pebble alone showed any unique characteristics, a grey banded rock with alternate layers of fine bedded material and cross-fibres respectively, both consisting essentially of quartz.

These pebble-bearing sandstones possess a width of outcrop perpendicular to the strike of 2·1 miles, corresponding to a thickness of some 2,000 feet, as shown on the accompanying map.

Subsequently, Dr. J. V. L. Rennie drew my attention to a similar occurrence of pebbles at Kidd's Beach, a few of which he collected. Here again the matrix of the pebbles is predominantly a coarse creamy or grey feldspathic sandstone with interbedded shales which dip due south at 15°. The pebbles are largest and most abundant from the beach stretching southwards along the shore for about three-quarters of a mile. They persist northwards beyond the mouth of the Umcantsi River, but then rapidly die out. Further to the south they also become less abundant, but continue in varying quantity for a great distance. In fact, they can be followed as far as the point just beyond Kayser's Beach, a distance along the coast only just short of 8 miles. The beds continue to dip south without any appreciable change of strike, but the amount of dip in general steadily diminishes southwards and is on the average about 5°. The width of the outcrop perpendicular to the strike is thus 5 miles, corresponding roughly to the same thickness of pebble-bearing sediments as before.

At Kidd's Beach the pebbles attain their greatest size, two or three actually exceeding 12 inches in maximum dimension. They again consist essentially of the same materials mentioned from the Kwelegha River crossing. In particular, however, a greater variety of coarse feldspathic grits is found, mostly characterised by pink feldspar and blue opalescent quartz; some are recrystallised to such an extent that it is difficult to distinguish them from porphyry and microgranite which also occur. One fine-grained grey granite is rich in garnets, and one pinkish porphyry is distinctive in possessing abundant phenocrysts which are all microperthitic feldspar. One pebble. 3 inches across, consists of a reddish granophyric base mottled with greyish green patches of chlorite. Among the sediments, greenish sandstones and more argillaceous types are found in addition to types previously mentioned.

Between the headland just south of Kayser's Beach and the Chalumna River mouth the strike of the beds exposed on the shore swings round through more than 90°, revealing a syncline with a strong pitch to the S.E. In this stretch no pebbles were observed, but just across the Chalumna River mouth to the south they appear again, though not numerous or large. Traced

further southwards, they increase in size and abundance and are well developed at the Kwani and Ngqinisa River mouths, where the enclosing reddish-brown sandstones dip E. 40° N. at about 5°. These pebbles are again made of the same rock-types. Just south of the Ngqinisa River mouth the last pebbles were found, thus representing their most southerly occurrence, and the fairly continuous outcrops from here to the Keiskama River mouth show no pebbles whatever.

Apart from minor irregularities, the structure of the beds exposed along the shore between the two localities of pebble-bearing beds referred to represents a broad anticline with its axis running roughly east-west through East London. In view of this there seems to be little doubt but that the two occurrences belong to the same horizon within the Beaufort series.

Exposures inland from the last occurrences mentioned, as in the extensive outcrops along the Payne's Drift cutting on the Chalumna River, reveal only occasional pebbles, suggesting that the farther inland we go the less frequent become the pebbles. As will be seen from the accompanying map, the pebble-bearing zone, lying here in a shallow pitching syncline, cannot outcrop much farther west than Payne's Drift. In the East London Public Library there is a map by George McKay, described as a Geological Plan of the Coastline between the Great Fish and the Juja Rivers, and on this map are indicated three points, one at Payne's Drift and the others near the coast between the Chalumna and Keiskama Rivers, at which, he says, there occurs a peculiar jaspery conglomerate containing fragments of petrified wood and pebbles of carnelian, agate, and chalcedony, set, as it were, in a paste of liver-coloured jasper. It seems likely that McKay was referring to the pebble-beds described here, although, if so, the other localities were apparently overlooked by him.

Apart from the occurrences just described, pebbles are conspicuously absent from the Beaufort series in the Eastern Province, and are rarely observed elsewhere. Dr. Broom (1912), however, described the occurrence of pebbles of quartz porphyry, quartzite and mica schist with quantities of silicified wood in the Lower Beaufort series of the Moordenaar's Karroo, and concludes that they were derived from formations to the north-east by river transport. Dr. S. H. Haughton (Rogers and others, 1929), referring to the varied lithology of the Lower Beaufort beds, states that in "northern Natal they are thick felspathic grits with little quartz-pebbles and occasional inclusions of granitic rocks," and infers the proximity there to an elevated region forming the source of the sediments.

The pebbles described here have very little to characterise them. Their shape varies from extraordinarily rounded to faceted and subangular, and they appear to possess no particular disposition or orientation. Of the igneous rocks represented, there appears to be a high proportion of reddish rocks, a coarse

granite with light-red microcline microperthite, colourless quartz and subordinate femic minerals partly epidotised being particularly conspicuous. On the other hand, not a single basic rock was observed in spite of special search. This is perhaps only to be expected in view of the low resistance of basic rocks to weathering, and yet the Dwyka tillite not far away frequently contains rounded pebbles of diabase and occasionally amygdaloidal basalt. It was thought possible at first that the pebbles in the Lower Beaufort beds were derived from Dwyka tillite which had become exposed by uplift during the Beaufort period, but there is no evidence in support of this, and the assemblage of materials composing the pebbles is quite different in the two cases. All that can be concluded is that the pebbles appear to be derived from land which lay to the south-east of the occurrences, as is indicated by false-bedding planes and the increasing scarcity of pebbles towards the west. It seems possible from the character of the materials concerned that the pebbles were derived in part from an exposure of red granite and felsites, perhaps comparable with the acid members of the Bushveld Complex, together with a great variety of other rock-types which show no particular affinities.

The beds have been referred to the Lower Beaufort, but there is little evidence of their age. It would seem that any distinction between Ecca and Beaufort in this coastal region must be based upon lithological characters, since no fossils have been recorded south of East London. The beds following the Upper Dwyka shales certainly comprise both arenaceous and argillaceous types, but consist largely of buff and dark-grey types, often highly carbonaceous. The first significant change in travelling up the coast appears to be the incoming of more highly coloured sediments, especially mudstones of various green, red and purple tints which occur fairly suddenly about the Begha River mouth, and may provisionally be regarded as the base of the Beaufort. Between here and the first occurrence of the pebbles at the Ngqinisa River mouth the beds dip steadily northwards.

In his map referred to, McKay states that at certain points on the foreshore of East London fossil reptiles are abundant, but in spite of intensive search I have managed to find only very occasional pieces of bone. Nevertheless, fossil reptiles have been found near East London which are regarded as having affinities with the Endothiodon zone. With this slender evidence, von Huene (1925) attempted to show on a map the distribution of this and the Cistecephalus zones, but the results are clearly tentative and, in fact, do not conform to the structure described above. If the beds outcropping at East London belong to the Endothiodon zone as shown on von Huene's map, then at least the pebble-bearing series here described is as young as this zone and may possibly belong to the succeeding Cistecephalus zone.

SUMMARY.

Outcrops of pebble-bearing sandstones of Lower Beaufort age occur on the coast both about 15 miles N.E. of East London and also to the S.W. of East London, from 15 to 30 miles away—that is, from Kidd's Beach onwards. They belong to the same horizon, the two occurrences being separated by an anticline passing through East London, while the second occurrence itself is in the form of a syncline. Both folds are pitching towards the sea. The pebbles comprise a great variety of rocks, many of the igneous rocks being conspicuously reddish in colour, and were apparently derived from a source towards the south-east.

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NOTE ON THE COLOUR OF COLLOIDAL SOLUTIONS OF COPPER OXIDE

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Read 6 July, 1939.

South African Journal of Science, *Vol. XXXVI, pp. 170-175, December, 1939.*

THE ORIGIN OF THE CALCAREOUS DEPOSITS OF THE RIETSPRUIT VALLEY

BY

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With 4 Text Figures.

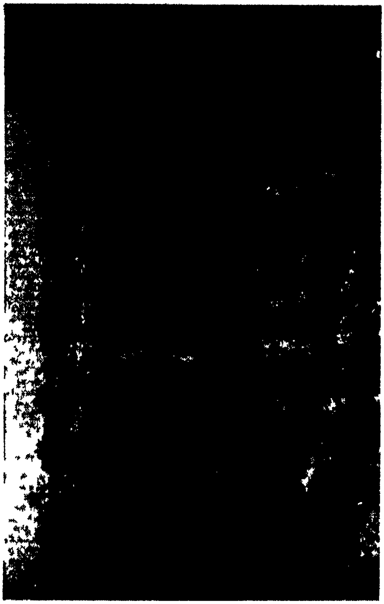
Read 6 July, 1939.

The peculiar deposits under consideration are scattered over large areas in the Orange Free State, so that conclusions reached need not be confined to the Rietspruit Valley. The particular section referred to, is that portion flanking the main railway line between Holfontein and Virginia with its centre at Whites, 30 miles south of Kroonstad. Exploitation of these deposits for the manufacture of cement has created an interest in them, which necessitates study of their origin. However, so far, literature on the subject has been conspicuous by its absence and such lack of published information constitutes the main inducement for writing this paper.

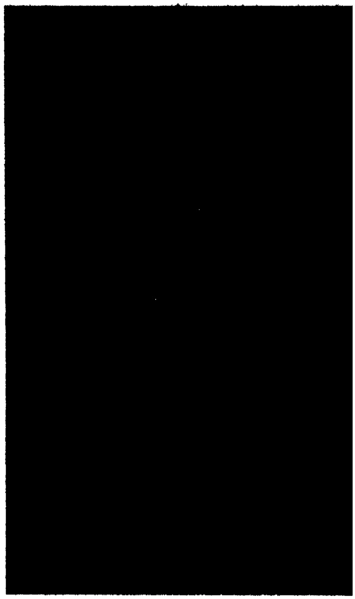
The limestone occurs in three principal varieties worthy of large scale exploitation. There are several modifications occurring in lesser quantities, one of which will be described because it has some bearing on the origin of one of the main varieties.

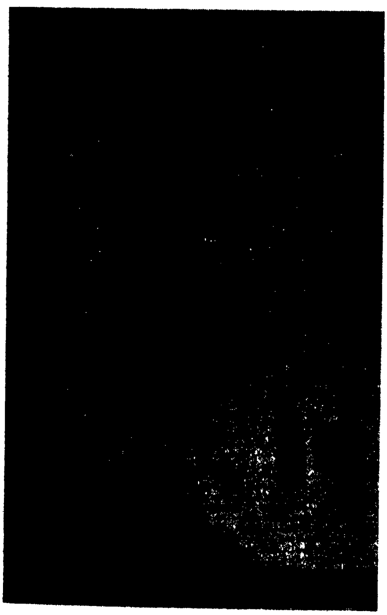
The Portland Nodular Limestone.

The nodular variety, occurring in our Portland quarries, has first consideration because of its economic importance, and because it provides the key to the origin of our friable Rietgat deposits. The first type occurs in the form of hard nodules of irregular shape, embedded in a matrix of sandy clay, averaging 12 feet thick, and is overlain by an overburden of about six feet of red soil. The limestone thins out towards the higher slopes, while the overburden continues to the foot of the ridge, where it ends in a thin layer close to the dolerites. Both beds have been badly eroded along the spruit, where, in some disturbed areas, limestone conglomerates have been formed. The clays vary in colour from white, through yellow, to greenish yellow, and the amount of nodular limestone included varies considerably in individual clay beds, though independent of the colour of the clay. In some instances, stratified beds of barren clay are found, and these may overlie, underlie, or be sandwiched between beds of limestone-bearing clay. An average working face is shewn in figure 1.



Fig





Fig

The chemical composition of the limestone nodules and of the clays varies between the following limits:—

	Nodular Limestone.				Clay.		
	%		%		%		%
SiO_2 ...	31·10	to	2·98	SiO_2 ...	74·00	to	66·40
Al_2O_3 ...	2·32		0·35	Al_2O_3 ...	12·40		16·40
Fe_2O_3 ...	1·18		0·54	Fe_2O_3 ...	4·00		3·40
$CaCO_3$ ...	61·50		94·69	CaO ...	0·80		3·40
$MgCO_3$ ..	3·02		0·70	Loss on Igt.	7·20		7·40
MgO ...	0·36		Nil.	MgO & Alkalis not determined			

In seeking an origin, the first step is to discover a parent source of lime, or clay, or better still, a common source of both. If one stands on the top of "Koppie Alleen," situated about 15 miles from Hennenman village, on the Odendaalsrust road, it will be observed that the Rietspruit Valley forms a flat basin, hemmed in by low ridges of dolerite. Boreholes sunk within the basin usually strike that rock formation at an average dept of 100 feet, while dykes are scattered throughout the area. Dolerite is made up of the minerals Labradorite Felspar, Augite, and Olivine, the first two being lime-bearing minerals, while all three are sources of clay.

A composite sample of specimens selected at random from material quarried at different points, gave on partial analysis:—

CaO – 10·02% MgO – 5·88% SiO_2 = 49·84%

The 10·02% calcium oxide would provide 17·88 tons of calcium carbonate per 100 tons of dolerite, and the 5·88% of magnesium oxide 12·30 tons of magnesium carbonate, a ratio of 1 : 1·45 which is out of all proportion to that shewn in the nodular limestone analysis, where the magnesium content is negligible. It is well known, however, that limestones of secondary origin are as a rule lower in magnesia than the parent formation, and contain silica, chiefly as quartz sand. This latter statement is also true in respect of the nodular limestone, which contains very little combined silica, most of the silica being present as finely divided quartz. Physical differences would account for the loss of magnesia, which being more soluble than lime would be carried further before precipitation from solution. Such has no doubt been the case, as patches of high magnesian limestones occur further south near Virginia, and are more abundant in the De Brug area, west of Bloemfontein.

A rough survey of the exposed limestone deposits, when viewed in conjunction with the 17·88 tons of calcium carbonate available per 100 tons of the parent rock, indicates pre-existing dolerite ranges of some magnitude. Allowance must, however, be made for the masses that have weathered down to form the low ridges of to-day.

Weathering of the alluvial materials would take place by the oxidation and hydrolysis, and the depth of the bed would be controlled by the amount of fresh material added to it during each wet season as against the amount of breakdown product resulting from these reactions and removed in solution, in colloidal form, or as finely divided non-colloidal solids in suspension. Thus the felspars would be hydrolised to form clays, while in the case of the anorthite molecule, lime would be released, and lime would also result as a product of augite, the calcium silicates and aluminates being attacked by carbonic acid in solution to form soluble calcium bicarbonate, which was later converted into the insoluble carbonate and so precipitated from solution. The primary clays were leached out of the alluvial beds and spread over the flats to form secondary clay deposits containing lime, partly in solution and partly as finely divided solids.

These clays cracked in the dry seasons, while swallow holes formed in the wet ones, leaving peculiarly shaped voids. Lime arrived in solution direct from the primary beds, or dissolved out from higher lying secondary beds, was deposited from solution in these voids to form nodules taking the peculiar shapes of the voids. Lime could also have been derived from other alluvial sources, though it is not the author's intention to discuss that problem exhaustively.

Equilibrium was eventually established between the rock of the parent ridge and the alluvial deposit at its foot. That is to say, a profile was attained wherein the ridge became so reduced that its contribution to the alluvial bed became negligible as compared with the removal of the alteration products from the latter. The minerals in the alluvium weathered progressively, and successive leachings eventually left a residual deposit consisting mostly of ferruginous sand. This was finally distributed over the secondary beds by wind and water to form the red soil covering of to-day. Samples of this red soil overlying the limestone deposits at Portland and on the farm Rietgat disclose rounded particles of dolerite and separate mineral grains.

Figure 2 shows a clay bed poor in nodular lime. The nodules near the top of the bed suggest the manner in which the fissures and voids received their infillings of lime with further concentration of lime at the bottom of the bed through precipitation from lime-bearing solutions flowing through the " washouts " in the lower strata and from downward-percolating waters.

Figure 1 shows an average working face in which concentration has resulted through elimination of the argillaceous portion.

A compact variety of limestone occurring as a sheet of solid travertine at the base of the beds shown on Figure 3.

Figure 3 has a calcium carbonate content of 96%. It is infrequent and lacks the economic importance of the nodular kind. It is often honeycombed with elongated cavities which extend horizontally and exhibit calcite crystals on their inner surfaces. The cavities are often so closely spaced as to give the stone a laminated

appearance, and the false laminae forming the dividing walls are frequently distorted. These compact travertines, no doubt, owe their origin to secondary enrichment by downward percolating waters.

The Helpmekaar Friable Limestone.

The soft friable limestone deposits shown on Figure 4 occurs on the farm Helpmekaar in the bottom of a dry pan, and are covered by a crust of hard calcareous sinter overlain by a few inches of black, peaty looking, soil. The sinter crust varies from half-an-inch to several inches in thickness, and becomes progressively more friable in depth, so that there is no well-defined line of demarcation between it and the underlying deposit. The pot-holed appearance of the crust is no doubt due to the solvent action of stagnant surface water rendered acid by decayed vegetation in the peaty soil.

Disintegration has resulted from roots entering cracks in the limestone, penetration being assisted by solution of the latter through acids secreted by the roots. The crust appears to have been formed through solution of the limestone by stagnant waters left in the pans after rains and precipitation as a calc-sinter from these waters on evaporation. The author's attention was directed by his quarry manager, Mr. Evans, to occasional patches of hard limestone occurring in small quantities among the friable material. An examination of this material revealed the same honeycombed cavity structure as was exhibited by the compact travertine sheet at the base of the Portland nodular beds.

Our chief chemist, Mr. West, reported that samples taken down the faces at Helpmekaar, indicated that generally the lime content decreased progressively from top to bottom, while the silica content increased. Inspection showed that the material became more sandy at depth, and that the lower levels showed signs of impoverishment by leaching. The present water-table in this pan is only twelve feet below surface level, and in wet seasons, before quarrying operations were commenced in the area, flood-water filled the pans to a few inches in depth. Similar observations were made in the case of another deposit on the farm Kalkfontein, some 25 miles distant. Here the limestone is definitely of the nodular variety, but not so compact as in our Portland deposits. The water-table also occurs at a shallow depth as at Helpmekaar, while the lower part of the bed is poorer in lime and richer in silica than the top. Porosity, due to leaching, was very marked. There can be little doubt that the friable materials occurring in the Helpmekaar deposit resulted from the decomposition *in situ* of a thick sheet of travertine limestone due to leaching, partly by successive drainage by downward percolation of rain waters already acidified by atmospheric carbon dioxide, but rendered more highly acid by virtue of decaying vegetation in the stagnant pans, and partly by the seasonable rise and fall of a shallow water-table.

THE RIETGAT PULVERULENT LIMESTONE.

A fine, powdery, white limestone occurs on the farm Rietgat in considerable quantities. It differs from the Helpmekaar variety in having the appearance, colour, and smooth texture of chalk, whereas the latter is darker in colour and coarser to the feel. There is no evidence of impoverishment at depth as in the case of the Helpmekaar deposit, or enrichment at depth as in the case of the Portland nodular limestone. The deposit occurs at a fairly high level and the water table is well below the quarry floor. A close examination resulted in the discovery of limestone "cores" *in situ* in various stages of decomposition; some were surrounded by concentric layers of decomposed limestone, which coatings unfortunately fell to powder when the core was disturbed. In the absence of impoverishment, or of enrichment at depth, it is difficult to visualise decomposition by flowing waters. Further, if we assume decomposition by stagnant waters with absence of drainage, cementation of the undissolved particles by lime re-precipitated from solution could be expected. This, however, has not occurred, and the mass has retained its powdery, chalk-like properties The most the author can say is that the deposit owes its origin to the decomposition *in situ* of a bed of nodular limestone.

In conclusion the Portland nodular limestone is of secondary origin, having been leached out of alluvial detritus formed by the breakdown of parent dolerite rocks, and precipitated from solution in voids in argillaceous materials derived from the same parent source. The Helpmekaar friable limestone resulted from the decomposition *in situ* of a thick travertine bed due to downward percolation of stagnant water and the rise and fall of a slow flowing shallow water-table, while the travertine owed its origin to the enrichment of the lower levels of a nodular bed, the upper or nodular portion having long since been eroded and carried away by the flood waters. The Rietgat powdery limestone was once a bed of nodular limestone.

A PSEUDOMORPH OF THE CALCAREOUS DEPOSITS OF THE RIETSPRUIT VALLEY

BY

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Read 6 July, 1939.

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THE FERTILITY REQUIREMENTS OF KIKUYU GRASS

BY

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AND

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TO

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Read 7 July, 1939.

So many farmers who put down pastures of kikuyu grass (*Pennisetum clandestinum*) Hochst. have reported unprofitable production or unpalatability, or both, that it seemed necessary to carry out an experiment on the relationship between fertiliser treatment, yields and composition in the coastal belt. Accordingly, a small plot experiment was put down with the primary object of determining the optimum dressing of nitrogenous fertilisers on sandy coastal soils. On these small plots no grazing was possible, and thus there was no return of nutrients to the soil—all cuttings being removed.

The results of experiments with this grass under grazing conditions in this area were reported by Moses (1934; 299) in 1934. Thus, in the 1933-34 season kikuyu receiving 700 lb. of fertiliser per acre, containing 83 lb. of nitrogen in the inorganic form, produced up to 15,000 lb. dry matter and 2,600 lb. crude protein per acre.

Taylor (1938; 319) has reported on grazing experiments on kikuyu at the Cedara School of Agriculture, in which the pasture in one camp receiving in 1935-36 300 lb. superphosphate, 600 lb. sulphate of ammonia and 35 lb. muriate of potash per acre produced 7,325 lb. dry matter containing 1,649 lb. crude protein, 30·8 lb. CaO and 61·0 lb. P_2O_5. The yields on other camps with the same fertiliser treatment did not vary much from these figures.

Description of the Experiment.

The area of grass on which the experiment was located had been planted as a nursery in November, 1930, and until the experiment was started in May, 1932, had received very little fertiliser. Four random blocks of plots each 15 feet by 15 feet were put down to treatments with two levels of phosphate application: 300 and 600 lb. 19·1 per cent. superphosphate per acre, and three levels of nitrogen application: 300, 600 and 900 lb. ammonium sulphate (21·1 per cent. N.)

per acre in three dressings per season. All plots received 1,000 lb. agricultural lime per acre in 1932, and for the first three years annual dressings of 80 lb. muriate of potash per acre. The grass was cut by hand when it reached a height considered suitable for grazing, and immediately weighed. Composite samples from each treatment were then placed in bottles for moisture determinations, and representative samples were taken for subsequent analysis.

In Table I the results for the first three seasons have been summarised. Seven cuts were obtained in the first year, nine in the second and six in the third.

TABLE I.—COMPOSITION OF KIKUYU GRASS BASED ON DRY MATTER.

Treatment in lb. per Acre	1932–33			1933–34			1934 35		
	Dry Matter	Crude Protein	% P_2O_5	Dry Matter	Crude Protein	% P_2O_5	Dry Matter	Crude Protein	% P_2O_5
	lb. per Acre			lb. per Acre			lb. per Acre		
300 Superphosphate + 300 sulphate of ammonia ..	10634	1357	0·74	8240	1104	0·95	4902	Not determined for this season	
300 P+600 S/A	12233	1682	0·75	10874	1624	0·93	6674		
300 P+900 S/A	13034	1869	0·70	11810	1808	0·88	7312		
600 P+300 S/A	10918	1282	0·76	8778	1170	1·04	5447		
600 P+600 S/A	11805	1573	0·74	11102	1603	0·93	6802		
600 P+900 S/A	14366	1935	0·73	11831	1735	0·95	7853		
Annual Rainfall in Ins.	31·31			50·81			39·18		

In the first season the CaO content varied from 0·52 to 0·56 per cent., and K_2O from 3·21 to 3·68 per cent. In the second season CaO varied between 0·54 and 0·61 per cent., and K_2O between 3·28 and 3·96 per cent. The figures quoted are annual averages for the six treatments.

In the 1935-36 season the plots were rearranged to form three blocks of eight plots each, and all plots received the same phosphate and nitrogen treatment, namely, 300 lb. 19·1 per cent. superphosphate, 300 lb. sulphate of ammonia (21·1 per cent. N.) and 300 lb. nitro-chalk (15·5 per cent. N.) per acre. Three potash treatments were compared with the following results:—

100 lb. KCl per acre—6,268 lb. dry matter.
200 ,, KCl ,, ,, —6,485 ,, ,, ,,
300 ,, KCl ,, ,, —6,176 ,, ,, ,,

The rainfall this year amounted to 43·65 inches. The decreased returns after the first two seasons suggested that perhaps the lack of organic matter and rarer elements might be a limiting factor in this experiment. Consequently, in September, 1936, one-half of each plot was given an application of 10 tons stable manure per acre. Unfortunately, the non-manure halves were not given at the same time the equivalent amount of inorganic nitrogen, and hence the increased yield of dry matter may represent merely the response to an application of manure containing nitrogen as compared with no nitrogen. If the different potash treatments are ignored, the average return of dry matter for one cut was raised from 631 to 1,501 lb. per acre by the manure dressing.

Subsequently, in December, 1936, the stable manure halves were given a further dressing of manure at the rate of 30 tons per acre, and at the same time the plots were halved at right angles to the first subdivision and one-half of each plot given the equivalent of 300 lb. ammonium sulphate and 300 lb. nitro-chalk per acre, i.e. 109·8 lb. nitrogen per acre, in the form of calcium cyanamide. The other half of each plot was given a small dressing of sulphate of ammonia at the time, and then later during the season the amount of nitrogen was brought up to 109·8 lb., with alternate dressings of nitro-chalk and ammonium sulphate. The effect of this subdivision was to divide each plot up into the following four sub-plots—receiving nitrogen as follows (assuming each ton of stable manure contained from 10 to 20 lb. nitrogen):—

(a) Stable manure + cyanamide ... 409·8 to 709·8 lb.
(b) Cyanamide ... ... 109·8 lb.
(c) Stable manure + ammonium sulphate and nitro-chalk ... ... 409·8 to 709·8 lb.
(d) Ammonium sulphate and nitro-chalk ... ... 109·8 lb.

Three cuttings were obtained during the remainder of the season. In the following season, 1937-38, no fertilisers were applied, and so the yields obtained in the two cuttings may be taken as residual effects of the previous season's fertiliser treatments.

Again ignoring the effect of the potash treatments, which gave no indication of any response, the results may be summarised as follows for the 1936-37 and 1937-38 season (see Table II).

The basal dressing given in the 1936-37 season was 300 lb. 19·1 per cent. superphosphate per acre. In the first year the rainfall was 37·03 inches, and in the second 39·95 inches.

After the cutting of 30th March, 1938, the plots were sorted out into four groups of six plots each, with the average yield of each group of six plots approximately equal. Each

TABLE II.—DRY MATTER PRODUCTION 1936-38.

Treatment	Dry Matter Production in Lb. per Acre		Increase of 1937-38 over 1936-37
	1936-37 (3 cuts)	1937-38 (2 cuts)	
Manure + cyanamide ...	5077	5876	799
Cyanamide	3330	4669	1339
Manure + ammonium sulphate and nitro-chalk	4605	6867	2262
Ammonium sulphate and nitro-chalk	3259	5812	2553

plot was given 519 lb. of 19·1 per cent. superphosphate and 208 lb. muriate of potash per acre. It was proposed to apply the following nitrogen treatments on the four groups, namely, 1,664, 832 and 416 lb. ammonium sulphate per acre per annum in four dressings, and one treatment with no nitrogen as a control. Actually only three of the four nitrogen dressings were applied. The results of the cuttings of May, 1938, and January, February and March, 1939, are presented in Table III.

TABLE III. - YIELDS OF DRY MATTER IN 1938-39.

Treatment	Lb. per Acre by Subplots			
	M + Cyanamide	Cyanamide	M + S/A + N/C	S/A + N/C
PK + 1248 lb. S/A -	12748	11107	14463	12066
PK + 624 lb. S/A -	10798	9676	10906	9685
PK + 312 lb. S/A -	7490	6394	9024	7579
PK - -	6333	5138	7836	6259

The rainfall from April, 1938, to March, 1939, was 48·96 inches.

The crude protein content of the herbage was determined for the three cuttings of January, February and March of this year and is shown in the accompanying Table along with the production of crude protein per acre for three cuttings (see Table IV).

DISCUSSION.

The results of the first three years show that nitrogen has given increased production, but there does not seem to be any increase in dry matter due to the doubling of the phosphate application. In the first two years extra phosphate also has not increased the P_2O_5 content of the herbage. Increasing the

amonium sulphate dressing from 300 to 600 lb. gave a greater return than the increase from 600 to 900 lb., although statistical analysis of the results has shown that only the difference between 900 lb. sulphate of ammonia and 300 lb. is significant at the 19:1 level during this period. A similar result has been obtained in cane experiments on this soil type, in which a significant response has been obtained by a high nitrogen treatment: 948 lb. sulphate of ammonia per acre, and not by a medium treatment: 474 lb. per acre. The crude protein figures for the first two years show the same general trend.

TABLE IV.—CRUDE PROTEIN CONTENT AND PRODUCTION 1938-39

Treatment	January		February		March	
	% Crude Protein	Lb. per Acre	% Crude Protein	Lb. per Acre	% Crude Protein	Lb. per Acre
PK + 1248 lb. S/A	6·1	257	13·9	385	18·7	537
PK + 624 lb. S/A	6·4	223	12·3	242	16·0	332
PK + 312 lb. S/A	7·3	228	12·1	157	12·9	165
PK	6·8	208	11·7	124	13·3	122

The introduction of the organic matter factor in 1936-37 and 1937-38 showed, first of all, that very poor yields were obtained compared with the results from fertilisers in the first two years of the experiment and with the 600 and 900 lb. sulphate of ammonia dressings in the third year. The comparison applies also to the 1938-39 results with 312, 624 and 1,248 lb. dressings of sulphate of ammonia.

It was unexpected that the manure subsections, receiving probably four to eight times the nitrogen, produced only fifty per cent. more dry matter than those receiving 109·8 lb. nitrogen in the inorganic form. It is also particularly noteworthy that in the second season of this treatment, when no fertilisers nor manure were applied, the yields from the residual effects with only two cuts were substantially greater than from three cuts in the previous season. Furthermore, the increase due to the residual effects of the treatments was greater from manure + sulphate of ammonia and nitro-chalk than from manure + cyanamide: 2,262 lb. as compared with 799 lb., and also greater from sulphate of ammonia and nitro-chalk as compared with cyanamide: 2,553 lb. to 1,339 lb. The greatest residual increase was given by the subsections receiving inorganic nitrogen as sulphate of ammonia and nitro-chalk and no manure, which is not in accordance with the view held by many grass workers that organic matter is the prime necessity.

The results of the last season show that manure is still giving slight residual effects, while the residual effects of

ammonium sulphate and nitro-chalk are greater than those of cyanamide. Ammonium sulphate at the rate of 600 lb. per acre is still able to produce on a kikuyu sward, which has been undisturbed for over six years, 4¾ tons dry matter per acre. and up to 6 tons with double this amount of fertiliser.

The January, 1939, cutting, which had been growing since the previous May, showed no result from increasing nitrogenous applications on the protein content, and even though a second dressing was applied on the 12th January the February cutting also showed no increase in protein content as a result. It is not until after the third dressing that marked effects on the protein content are noted. This would indicate that on old stands of kikuyu, where the soil is permeated with a mass of roots, nitrogen applications below a certain level give more grass without increasing the protein content, while above this level production and protein content are increased. In general, this experiment shows that on this soil type under coastal climatic conditions kikuyu requires heavy dressings of nitrogen for the best results, probably 900 to 1,000 lb. sulphate of ammonia per acre per annum. Inorganic nitrogen in the form of sulphate of ammonia and nitro-chalk, applied alternately, has given better results than cyanamide.

For the production of protein and dry matter at the levels obtained in this experiment, from 300 to 500 lb. superphosphate per acre seem to be sufficient. Increasing the potash applications above the level of 80 to 100 lb. per acre per annum had no marked effect on production.

After the first three years of the experiment the plots were selected to form the different groups, and hence no statistical analysis of plot yields or group totals is possible. Examination of the subplot yields has shown, however, that high amounts of nitrogen either as manure or manure with inorganic nitrogen have given results that are significant at a very high level as compared with those given by the low amounts. Furthermore, statistical analysis of the yields for the two years following the original calcium cyanamide dressing has shown that sulphate of ammonia and nitro-chalk gave residual effects significantly superior to those of cyanamide. In fact, there seems to be definite evidence that calcium cyanamide after its stimulating effect of the first year has exerted a depressing effect on production.

Summary.

An experiment on kikuyu grass on sandy soil with three nitrogen and two phosphate treatments is described. All plots received a basal dressing of potash and lime. The plots were cut by hand, and all grass clippings were removed.

For the first three years doubling the phosphate application gave no increase in yield over the single dressing, while analysis of the herbage for the first two years showed no increase in

phosphate content for the double as compared with the single dressing.

Nitrogen in the form of sulphate of ammonia increased the yields of dry matter and protein, but the differences between the 300, 600 and 900 lb. sulphate of ammonia per acre per annum dressings were significant only for the increase given by 900 lb. as compared with 300 lb.

In the fourth season all plots received the same phosphate and nitrogen applications, and three levels of potash application were compared. Increasing doses of potash, however, had no effect on dry matter production.

Manure was applied to halves of all plots in the fifth season, and calcium cyanamide on half plots was also compared with sulphate of ammonia and nitro-chalk in alternate dressings. In the sixth season the residual effects of these applications were compared, as no fertilisers were applied.

The results during these two seasons showed that nitrogen either as manure or in the inorganic form increased yields, but heavy applications of manure containing four to eight times as much nitrogen as inorganic dressings gave only fifty per cent. more dry matter.

The residual effects of sulphate of ammonia and nitro-chalk appeared to be distinctly superior to those of cyanamide, which seemed to have a depressing effect after the first season.

In the last year reported three levels of application of sulphate of ammonia were compared. Nitrogen increased yields of dry matter, but it was not until after the third application that any appreciable effect on the protein content was noted.

As a result of this work, it is concluded that kikuyu grass on this soil type requires about 300 lb. superphosphate, 100 lb. muriate of potash and up to 1,000 lb. sulphate of ammonia per acre per annum in order to remain productive and yield herbage of a high protein content.

Acknowledgments.

The writers wish to thank Mr. T. D. Hall, Agricultural Adviser to African Explosives and Industries, Limited, for his interest in this experiment and for permission to publish the results, and Mr. L. S. West for carrying out all the field work.

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NOTE ON SOME CHERTS IN THE KARROO SYSTEM

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With 4 Text Figures.

Read 7 July, 1939.

Although chert is well known from the Upper Dwyka shales, and indeed a chert band is taken in the southern portion of the Cape Province as the topmost horizon of the Dwyka series, nevertheless descriptions of this material are somewhat meagre. It is not the intention here to traverse the ground covered already in the literature on the subject, nor even to deal comprehensively with one aspect such as the petrography of chert in the Karroo System, but merely to describe special material familiar to the authors.

In the neighbourhood of Grahamstown cherty material is frequently found in the White Band which occupies a remarkable series of aligned valleys stretching from the tenth milestone on the Queen's Road to Fort Brown, as shown on Geological Cape Sheet No. 9 (Port Elizabeth), to Hunt's Hoek at the big meander in the Fish River below Hunt's Drift. Beyond this the same horizon becomes less conspicuous, but still shows signs of containing cherty layers.

The most characteristic chert is found in the road cutting on the Queen's Road itself, and has been mentioned by Dr. Haughton (1928, p. 14). Here the White Band consists of some 30 or 40 feet of highly contorted whitish weathered shale sandwiched between beds dipping uniformly at 30-35° towards the north. In the uppermost 10 feet of this band the bedding is somewhat obscure, and about 7 feet from the top occur irregular but somewhat platy masses of cherty material intimately associated with the white weathered shale.

This chert varies in colour from pale to dark grey, is sometimes slightly brownish but rarely quite black. It shows almost universal colour-banding on a fine scale and tends to split roughly parallel to this banding. That this banding is original bedding is clear from the hand-specimen, in that it passes into the bedding of contiguous shale and in places shows false bedding; it also shows a certain amount of contortion. Relics

of white shale occur entirely enclosed by chert and leave little doubt that Dr. Haughton was correct in ascribing the chert to silicification of the original shale. The distribution of colour in the chert shows no relation to the accompanying shale and, apart from the banding, appears to be the result of alteration of the chert itself.

It is traversed by a network of pale streaks and shows numerous small spots where alteration has taken place and some of the former are actually crystalline in the middle as tiny quartz veins. Cavities and surfaces of contact with the shale are frequently lined with clear quartz crystals or bluish-grey chalcedony.

The fresh-looking material, whether pale or dark grey, is unscratched by a pocket-knife, but the paler material generally represents various degrees of weathering and is then correspondingly softer. The darkest fresh chert has a specific gravity of 2·57, whereas that of the pale material when fresh is less than 2 55, figures which indicate that all the material is very impure. The pale material, when crushed, is nearly isotropic and has a refractive index of about 1·530, considerably less than that of quartz.

Thin sections show it to be a uniform very fine-grained rock, somewhat turbid, with grains up to 5 μ in diameter, but generally much smaller, and enclosing nests and veins of much coarser material consisting of quartz, chalcedony and epidote. The banding consists of brown staining, which becomes opaque in the darkest bands. Parallel to the banding are some small original flakes of mica about 5 μ in thickness and 25 μ in length, confirming the banding as bedding planes. As one would expect in such a rock, no organic remains are to be observed.

An analysis of the typical dark grey chert gave the results shown in Column 1:—

	(1)	(2)	(3)
SiO_2	86·73	90·87	98·79
TiO_2	trace	0·24	none
Al_2O_3	6·12	3·70	0·21
Fe_2O_3	1·98	0·34	0·40
CaO	0·23	0·31	0·10
MgO	trace	0·33	0·02
H_2O (below 110° C.)	4·04	4·36	0·06
H_2O (above 110° C.)			0·30
	99·10	100·15	99·88

(1) **Dwyka Chert: Analyst E.D.M.**
(2) **Dwyka Chert: Analyst J.J.F.**
(3) **Molteno Chert: Analyst J.J.F.**

Hygroscopic water was determined as 1·08 and the total water as 2·90 per cent. by condensation; the figure 4·04 given is the percentage ignition loss, so that the remaining 1·14 per cent. represents other material driven off by ignition. During ignition the colour of the powder became almost white, indicating that the dark colour is due to carbonaceous material. The figure given for Fe_2O_3 is based on the total iron, but magnetite was further separated magnetically from 5 grams of the powder and gave 1·40 per cent. At least some potash must be present in the mica, but it was not determined, though it is probably present as only a trace. With dilute hydrochloric acid, even on warming, no effervescence occurred, showing that no carbonate is present. Another analysis of material from the same locality is given in column (2), and although hygroscopic water was determined as 1·35 per cent. and total water as 3·32 per cent., there was an ignition loss of 1·04 per cent. remaining, a feature similar to that in the previous analysis.

Elsewhere in the Upper Dwyka Shales of the Grahamstown district cherty rocks are represented by compact fine-grained silicified mudstones and dolomites. These latter, occurring in impersistent bands up to 20 feet in thickness, vary from highly siliceous types to almost pure carbonaceous dolomite. Specimens containing only a small percentage of silica may easily be mistaken for chert, for in appearance they are fine-grained, black, break with a conchoidal fracture, do not effervesce with dilute hydrochloric acid in the cold, and are often difficult to scratch.

During January of this year, while examining the relationships of a dolerite intrusion in a quarry about two miles south of Vineyard, on the Aliwal North-Jamestown road, one of us (J.J.F.) observed a thin band of chert interbedded with dark blue and grey shales of the Molteno beds. No descriptions of the occurrence of chert in the Molteno beds have been published, although cherty material is known in association with plant-bearing rocks in these beds, as kindly mentioned privately to us by Dr. A. L. du Toit.

The rock here occurs as a fairly persistent band varying from two to six inches in thickness, with a tendency to develop into lenticular bodies up to two feet long. It is intercalated in a yellow-grey highly silicified clay-like rock possessing vague structures which might possibly have been plant tissue. Above and below this latter rock are grey shales with definite remains of plant structures and dark cherty shales with perfect remains of Molteno flora. The chert macroscopically is, for the greater part, dark grey to black, with slightly irregular alternating pale and dark bands up to two millimetres in thickness, the dark bands being more abundant. Although there is as a rule, a sharp break between chert and the yellow-grey cherty rock, gradations between the two have been noted, and in such cases the banding in the chert is disturbed. The rock breaks with a sub-conchoidal

fracture or along planes parallel to the banding. It is traversed by numerous thin cracks, small faults and quartz veinlets. It has a specific gravity of 2·59.

In thin section the definite macro-banding becomes vague. The wide bands are seen to be composed of numerous thin bands of which more are present in each dark macro-band than in the pale ones. There is an abundance of yellowish-brown spots in the sections examined and which are probably iron oxides.

The whole rock under high power resolves into a fine mosaic of quartz particles of 5 μ diameter with abundant layers of dark opaque material separating and often almost surrounding the quartz particles. Where the dark material, which is probably carbon, diminishes, some of the quartz granules increase in size up to 30 μ. The refractive indices of the fine-grained material from several specimens were determined, and in no case did they indicate any form of silica other than quartz.

The veinlets traversing the chert are in most cases at right-angles to the banding, and are often displaced either by larger veinlets or by planes cutting across the banding. The hard rock of specific gravity 2·57 occurring above and below the chert, and with which it sometimes merges, when examined in thin section shows vague banding, contains a large number of angular quartz grains and also structures which might possibly represent plant remains. With the merging of the dark chert into this lighter material the increase in grain size is very striking.

The finest-grained banded chert may possibly be a syngenetic deposit formed by the precipitation of a silica gel, but the lighter coloured portions are probably silicified sandy and finely bedded shale. At the time of formation of the sediments, the amount of silica in solution may have increased with decrease of grain size of the materials deposited until a phase was reached where colloidal precipitation took place.

Although a faint line marks the fault planes in the fine-grained chert, in thin section the faulted material is seen to have healed perfectly without any quartz or chalcedonic cement. This fact would strengthen the gel precipitation theory. (Tarr, 1926, p. 43.)

Mrs. M. Moss, of the Botany Department, University of the Witwatersrand, very kindly examined the sections and rock specimens and could find nothing in the chert which would definitely suggest plant remains. Nevertheless, the associated sediments contain plant tissue and well-preserved fossils.

The dolerite intrusion has disturbed the sediments a good deal, but away from the contacts the relationships between the chert and silicified clay are well defined. The veinlets of quartz are probably due to shrinkage cracks formed in the silica gel being subsequently filled. This chert was analysed and the results are given in column (3) above.

This analysis shows a very much higher silica content than those of the Dwyka chert, and coupled with the different mode of

occurrence certainly bears out some difference in origin of the two chert horizons as suggested previously. The water content is small contrasted with that of the Dwyka chert, and it is possible in the latter that some of the combined water in addition to that of clay is present as opaline matter. This receives some support from the low refractive index of the ground-mass. Apart from the chemical composition, the two cherts show marked structural differences in regard to the nature of their banding, as is clearly demonstrated by the photomicrographs. On the other hand, they have this property in common that they owe their dark-grey coloration to disseminated carbonaceous material.

We are indebted to Professor G. H. Stanley and the Minerals Research Laboratory Committee for permission to publish the laboratory data obtained by one of us (J.J.F.). Thanks are due to Mrs. Moss for examining the plant remains and to Mr. J. Levin for photographs.

Summary.

Chert is described with chemical analyses from two distinct horizons within the Karroo System. One from the Upper Dwyka beds occurs some ten miles north of Grahamstown; the other, from the Molteno beds, was discovered between Jamestown and Aliwal North. Differences between them are ascribed to slightly different modes of origin, both being due to metasomatic alteration of shale, and the latter possibly in part being derived by precipitation from colloidal silica as well.

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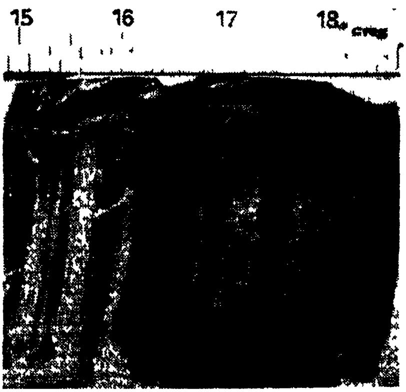

Fig. 1—Molteno Chert, Polished Surface.

[Photo J. Levin.

Fig. 2—Molteno Chert × ½. Polished Surface.
[Photo J. Levin

Fig. 3.—Photomicrograph × 300. Molteno Chert.
[Photo: J. J. F.

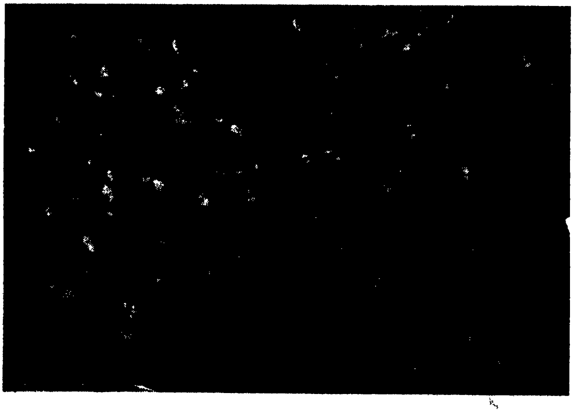

Fig. 4.—Photomicrograph × 85. Dwyka Chert.
[Photo: J. J. F.

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SOUTH AFRICA'S OLDEST LIVING CITRUS TREES

BY

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With 2 Text Figures.

Read 3 July, 1939.

While it has been proved that the first introduction of citrus trees into the present Union of South Africa was on 11th June, 1654, these being orange trees, in all probability seedlings, from St. Helena, it may safely be supposed that Southern Africa had citrus growing in it before then. The Berbers and Arabs had been voyaging to the East Coast for trade and slaves for a hundred years and more before this, while Portuguese Jesuits also operated on this coast. It may well be assumed that, accidentally or otherwise, citrus trees established themselves in Southern African soil from seed from fruits carried by such adventurers. The rough lemon thickets growing wild in Southern Rhodesia and the scattered presence of seedling citrus trees in Eastern Central Africa might well be the outcome of introductions over 500 years ago.

This article, however, is concerned with individual trees, and places on record information which might not be available in later years. The earliest plantings of citrus were of seedlings, but, with the commercialisation and improved production methods of the citrus industry in comparatively recent years, such seedling trees are rapidly disappearing. In " Riebeeck's Journal " mention is made that Van Riebeeck picked the first oranges in the Company's gardens in 1661. No mention has been found as to what age these first trees in the Union lived.

Actual documentary proof of which is the oldest living citrus tree in the Union cannot be offered, and, while not wishing to start a controversy, the writer hopes that much additional evidence and information will be submitted by those having such knowledge.

The oldest tree of which the writer has knowledge was burnt almost to ground level in 1925, at which time it was definitely at least from 150 to 160 years old. New suckers grew out just above the crown roots, and Fig. 1, taken in 1930, gives some idea of what the circumference of the trunk of the original tree must have been. Portions of the original trunk can be seen, being almost over-grown by the new suckers which have developed into trees themselves. This tree, a seedling orange, stands on the farm " Hex River " belonging to Mr. Polly Visser in the Clanwillian district. The evidence on

which the age of the tree is estimated is that of the late C. J. Mouton, who was born 126 years ago, and who maintained that this tree, together with two companions, were very large in his boyhood days. His father had often told him that when he (C. J.'s father) first settled in that area, some 130 years ago now, the Hottentots used to tie their cattle to the trunks at night, and during the day the trees provided shade for the same cattle. Who knows but that the trees were then already 50 or 75 or more years old?

If it is accepted that the circle of suckers, now trees, are part of the original tree, as undoubtedly the roots are, then the oldest known living citrus tree in South Africa is at least 160 years old.

Fig. 1.—Stump of Hex River seedling orange tree at least 160 years old.

Of seedling citrus trees over 100 years old there are plenty to-day in the Cape Province, particularly in the Clanwilliam district, but *mal-di-goma* and neglect are taking their toll. Within a few hundred yards of the old tree discussed above is a very old seedling orange orchard with only a few blanks in it. The trees were planted by C. J. Mouton's father 130 years ago, the seed being obtained from the three very large seedlings on the property. Forty years ago the orchard was cut down to stumps and the tops burnt in an effort to get rid of "Australian bug," but, as seen in Fig. 2, the orchard rapidly re-established itself Adjacent to this orchard is a naartje (tangerine) tree planted by C. J. Mouton as a boy over 100 years ago.

Old trees, individually and in plantings, well over 100 years old, are to be found in the Clanwilliam district at "Klaver Vlei" and at "The Baths" near Citrusdal. In the Graaff-

Reinet district trees 120 years and more old are still to be found.

The early settlers in the Western Transvaal planted citrus seedlings near their homesteads, but there are very few trees, if any, over 80 years old; the drought of 1932 resulted in whole orchards of seedlings from 50 to 70 years of age dying.

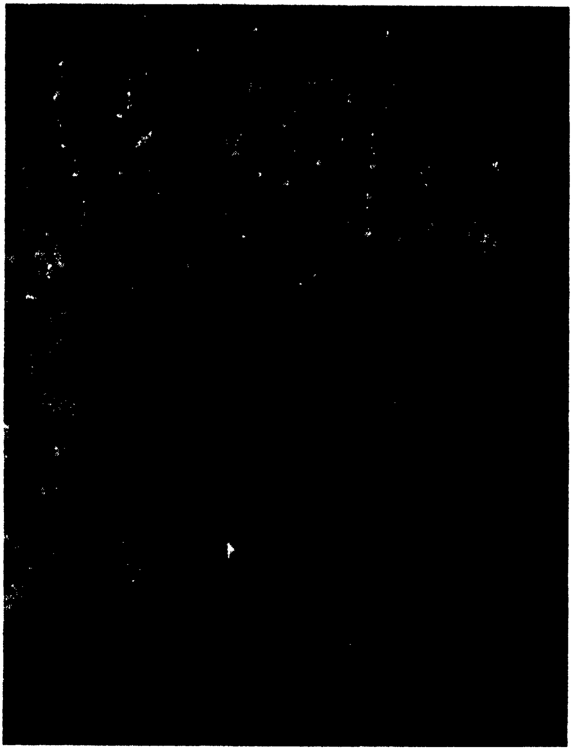

Fig. 2.—Tree in seedling orange orchard at Hex River known to be 130 years old.

All the trees mentioned here are still healthy and produce huge crops regularly, particularly where they are given care. In 1895, when the trees were at least 100 years old, C. J. Mouton picked and counted close on 19,000 oranges from the three old trees at Hex River, the equivalent of about 30 export cases of fruit per tree! In the Rustenberg district some seedling orchards from 30 to 40 years old yield an average of 20 packed export cases per tree, the fruit being of the highest quality, a disadvantage being that the fruit is seedy.

When one comes to consider budded or grafted citrus trees as distinct from seedlings or layered trees, the relative ages of existing plantings differ greatly. While the younger ages of budded trees is no doubt due to the fact that it was only in the last fifty years or so the world made rapid strides in citrus-

tree propagation, and development from the "backyard planting" stage took place, there is no doubt that the possible life of a budded or grafted tree is considerably less than that of a seedling or layered tree.

Some of the oldest plantings of budded citrus trees in the Union are to be found in the Groot Drakenstein Valley in the Cape and around Grahamstown and Fort Beaufort. As early as in 1850 the Bahia (Navel) orange was imported from Brazil, and in 1854 grafted trees of this variety were distributed by Mr. W. Tuck of Grahamstown for planting. Unfortunately, no record whether any of these trees are still alive or how long they lived exists. Mr. D. Roberts of Fort Beaufort has a Washington navel orchard 35 years of age, and Mr. H. E. V. Pickstone of Groot Drakenstein has a lemon orchard of budded and top-worked trees over 40 years old. It would be of great value to obtain more information as to the existence and location of the oldest plantings of budded or grafted citrus trees in the Union, for some concern is being felt as whether about 25 to 30 years is not the age limit for profitable production of most of the commercial citrus orchards in this country under the cultural conditions practised in the past and at present.

For comparison, it is interesting to mention some of the oldest seedling citrus trees known to the writer elsewhere in the world. The home of citrus is in the East, particularly China, but climatic conditions are such there that the citrus is a comparatively short-lived tree. No information is available to the writer of what might be considered a very old citrus tree in the Orient. Recently it was claimed that in Spain there is a seedling tree over 230 years old, but authentic records are lacking. This tree is undoubtedly of great age, but it might be only 150 years old. The oldest citrus tree in California may well be over 100 years old; documentary proof gives the oldest as being the Bidwell Bar tree planted in 1854 and now 85 years old, but other evidence might be accepted to show that the Patton trees are considerably older.

An unusual authentic record of an old orange tree comes from Finland, where for 86 years a tree has survived. This tree is growing in a container, kept in-doors every winter and moved out-doors in summer. In Florida a seedling orange grove is over 90 years old. while on the Skinner property adjacent there is a huge seedling grapefruit tree now just over 100 years old. In Brazil and in the Argentine there are many individual trees and small plantings of citrus which appear to be very old, but the oldest trees the writer encountered in Brazil were orange seedlings at Limeira now only 65 years old.

It is not contended that the full record of South Africa's oldest living citrus trees has been given here; it is difficult to obtain authentic records, but it is hoped that interest will be stimulated, resulting in bringing to light further information on a subject which, while of not much practical value, should be of undoubted general interest to all workers in citriculture the world over.

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CITRUS ROOTSTOCK INVESTIGATIONS: I. INFLUENCE ON YIELD AND FRUIT QUALITY OF FIRST CROP BORNE *

BY

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Read 3 July, 1939.

Abstract.

This is the first paper of a series which will present results obtained from the very extensive and comprehensive investigations being conducted by the author on citrus rootstocks throughout the Union, the main plantings, started in 1935, being at the Subtropical Horticultural Research Station, Nelspruit, E. Transvaal.

The first commercial crop was borne in 1939 on trees of Valencia orange, Washington navel orange, Triumph grapefruit, Natal naartje (tangerine), and Lisbon lemon budded on three rough lemon selections, three sweet orange selections, and one trifoliata stocks. It is desired to find out whether the stocks as a group differ in their influence on scions, and whether there are any different effects of the members within groups. The orchards are laid out on the randomized block system, allowing statistical treatment of the data obtained. This year only the data from the Natal naartje were analysed. The values determined for all were: yield per tree in weight, number of fruit, size per fruit, rind thickness, per cent. juice, per cent. total dissolved solids in juice, per cent. acid in juice, and ratio of solids to acid in juice. The fruit quality tests were made in accordance with technique evolved which it is believed gives a true reflection of the actual condition for the whole trees while only representative samples were tested.

In general, the results show that for all varieties trees on sweet orange stock in the first year of commercial bearing have only half the crop borne on trees on rough lemon stock, despite being of about the same size; this difference disappears a year

* The complete paper, including six tables and full discussion, is to be published later after further confirmatory data have been obtained.

or two later. The fruit from trees on sweet orange stock are slightly smaller, have a higher total soluble solids and acid content (significant), and probably have a higher juice content and a thinner rind. Trees on trifoliata stock are comparatively smaller, bear only small crops at first, but the quality of the fruit is of the highest, the differences between fruit from trees on sweet orange and rough lemon stocks being accentuated for trees on trifoliata stock. As the trees grow older and come into full bearing it will be seen whether these differences persist; data is available that they do persist up to the seventh year after planting out.

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THE DEVELOPMENT OF THE OVULE AND SEED OF JOINTED CACTUS (*OPUNTIA AURANTIACA*, LINDLEY)

BY

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With 26 Text Figures.

Read 6 July, 1939.

Introduction.

It is commonly known that Jointed Cactus spreads rapidly by vegetative propagation, but the possibility of infection by seed must also be considered. Workers in the field have commented on the scarcity of seedlings, and in consequence have come to regard the dissemination of the pest by this means as insignificant. While the danger is limited by the very small amount of viable seed produced, yet it must also be considered since the seed is protected by a very hard seed coat which ensures a prolonged period of dormancy.

This investigation shows why germination only takes place sporadically in nature, how polyembryony occurs, and why the percentage of viable seed is so low.

The work is part of a general morphological and physiological study of the Jointed Cactus, and was spread over a period of three years, during which time numerous field excursions were made. The pollination experiments mentioned in the text formed part of three weeks' field work carried out on the infected area of the Uitenhage Commonage.

Literature.

Literature dealing with the ovule and seed of *Cactaceae* may be divided into two periods. The earlier period starts in 1852 when Payer mentioned the structure of ovules in species of *Opuntia* and *Cereus* (Engler-Prantl, Naturliche Pflanzenfamilien, 21, 607: 1925). This period includes work by Guignard (1886) on ovular structure and fertilisation, by d'Hubert (1896) on the formation and development of the embryo sac and by Ganong (1898) on polyembryony. The second period, apart from one or two records of adventitious embryo formation and polyembryony. contains papers by Huber (1929), Mauritzon (1934) and Neumann (1935), who were chiefly concerned with the evidence which embryo sac formation in species of *Opuntia*, *Rhipsalis*, *Nopolea* and *Pereskia*, gives for the classification of the *Cactaceae*.

I was unable to obtain the works of Huber and Mauritzon, but full summaries were respectively found in Biological Abstracts (1930: 22497) and in Neumann's paper (loc. cit.).

The Ovule.

The Ovule in *Opuntia aurantiaca* is neither orthotropous, anatropous not campylotropous. For this reason it is interesting to note how previous writers have described the ovules of other members of the *Cactaceae.*

Payer (Engler-Prantl, 21: 607: 1925) has indicated that the ovule, presumably of *Opuntia* sp., describes a complete spiral before it develops into an anatropous ovule. Ganong (1898: 222) says "the ovule of *O. vulgaris* is at first amphitropous, but in its development it becomes elongated and bent, at the same time turning round in such a way that the funiculus makes a complete turn around it, and it finally resembles a campylotropous condition." In *O. ficus indica* the funicle is said to surround the ovule completely and to be like a thick third integument d'Hubert (1896) (ex Schnarf, p. 55, 1928). According to Vaupel (1928) (ex Engler-Prantl, p. 609, 1928) the ovule of *Opuntia* and *Nopolea* in longitudinal section appears to be enclosed in a peculiar envelope which is to be regarded as an extraordinary enlargement of the fold of the funicle, the fold of the funicle being the broadening out of the funicle in the neighbourhood of the micropyle as occurs in *Peireskia* spp. According to J. A. Huber (1929), the ovule in *Opuntia*, *Peireskia* and *Rhipsalis* is campylotropous with a long funiculus, and the third integument of *Opuntia* is interpreted as an enlargement of the funicle. Johnson (1918) describes the seed of *O. fulgida* as having a protective jacket which is "derived from the funiculus, and surrounds the seed completely, having finally closed in above the micropyle."

The following account of the development of the ovule in *O. aurantiaca* shows how it is possible for the funicle to surround the rest of the ovule and in what order the encirclement takes place.

A small knob-like swelling of the ovary wall elongates and forms the funicle. The tip of the funicle then bends down and integumentary and nucellar initials arise from it (Figs. 1, 2, 3). As the integuments and nucellus develop, the cells on the outside of the funicle divide and elongate much more rapidly than those on the inside, so that the rest of the ovule, i.e. the integuments, nucellus, etc., is forced to make a complete circle, and when the embryo sac is fully developed this part of the ovule once more lies in an anatropous position (Fig. 4).

A series of transverse sections of the ovule at the time of embryo sac formation show how the margins of the funicle grow out and eventually fuse with the parts of the funicle opposite (Figs. 5-9). In the very young stages the line of fusion can just

be distinguished (Fig. 10), but by the time adventitious embryos are formed all traces of fusion have disappeared.

A longitudinal section (Fig. 4) shows the spiral canal, along the inner surface of the funicle, leading round to the micropyle. The entrance to this canal is a small opening at the base of the funicle where lateral fusion does not take place.

If these facts are considered in addition to those recorded by Payer, d'Hubert, Ganong and Huber, it seems highly probable that this type of ovule is a characteristic of the genus *Opuntia*. If such is the case it would be incorrect to say, as Johnson does of *O. fulgida*, that the micropyle is the last portion to be covered. On the contrary it is one of the first parts to be surrounded.

The ovule at the time of embryo sac formation might be spoken of as anatropous, but actually, in making the one and a half spiral, it has passed through all the positions recognised in ovular terminology, and perhaps a more appropriate term than anatropous would be circinotropous.

In *O. aurantiaca* two ovule initials often arise side by side, and as they develop their funicles fuse at the base and give the impression of two ovules arising from a single funicle. This might be compared with *Cereus tortuosus*, where the principal trunk of a funicle gives rise to about 30 branches or secondary funicles each terminated by an ovule, Guignard (1896).

The funicle is traversed by a vascular strand which ends in the chalaza. The inner surface of the funicle forming the canal is covered with short hairs or papillae. These papillae are particularly noticeable at the base of the funicle near the opening to the canal, and inside the ovule where the funicle touches the micropyle. They are directed towards the micropyle. Similar papillae occur in species of *Rhipsalis*, *Nopolea*, *Pereskia* and *Cereus;* Guignard and others think they help to direct the pollen tube to the micropyle.

The micropyle is formed by the large, flared protruding ends of the inner integument (Fig. 11). The outer integument is much shorter and takes no part in the formation of the micropyle. Both integuments, except at their tips, are formed of only two layers of cells, not three as Ganong (1898) found in *O. vulgaris*. The structure in *O. aurantiaca* corresponds with that found in species of *Opuntia*, *Peireskia* and *Rhipsalis*, Huber (1929). Another feature it has in common with other members of the Cactaceae is the conspicuous air space which occurs between the inner and outer integuments (Fig. 4).

Once the funicle has completed the first circle, the nucellus increases rapidly by anticlinal and periclinal divisions. A nucellar cap is formed by the radial elongation of the epidermal and cover cells (Fig. 11). These elongated nucellar cap cells are also distinguished by their large nuclei and dense protoplasm. In length they correspond to about two or three neighbouring

nucellar cells. A somewhat similar nucellar cap structure is reported for *Pereskia amapola var. argentina*, Neumann (1935) and *Rhipsalis* spp., Mauritzon (1934). Neumann suggests that they afford an easy passage for the pollen tube to the embryo sac. As will be seen in the section dealing with embryo formation the form of these cells is especially significant.

Neumann (1935) points out that the air space between the inner and outer integuments, the structure of the micropyle and of the integuments, the crassinucellate nucellus and the well-developed hair zone of the funicle are characters of the *Cactaceae* which correspond with those of other *Centrospermae* and which support the classification of the *Cactaceae* in this group. These characters show that *O. aurantiaca* is a typical member of the group.

The Development of the Embryo Sac.

The terminology used below in describing the development of the embryo sac is similar to that used by Maheshwari (1937) in his critical review of embryo sac types in Angiosperms.

When the funicle has nearly completed its first circle the archesporial cell is initiated (Fig. 12). It cuts off a wall cell and forms the megaspore mother cell (Fig. 13). The megaspore mother cell divides giving the two-celled dyad stage (Fig. 14), and a further division of the lower dyad cell gives a row of three cells, the uppermost being an undivided dyad cell (Fig. 16). It is this uppermost or micropylar cell which forms the eight nucleate bisporic embryo sac (Figs. 17, 18).

This development differs slightly from that occurring in other members of the *Cactaceae*. In *Pereskia* Neumann, and *Rhipsalis* Mauritzon, two cover cells are formed. In *Pereskia* there is a tetrad of four megaspores of which the chalazal forms the embryo sac. *Rhipsalis* is similar to *O. aurantiaca* in having a row of three cells, i.e. an undivided dyad cell and two megaspores, but it is the chalazal megaspore and not the dyad cell, as in *O. aurantiaca*, which forms the embryo sac.

The eight nucleate bisporic embryo sac of *O. aurantiaca* may be said to correspond to the *Allium* type of embryo sac formation, Maheshwari, the only difference being that in *O. aurantiaca* it is the micropylar and not the chalazal cell which forms the embryo sac. Sometimes there are two archesporial cells which divided simultaneously to form twin dyad and three-cell stages, but only one embryo sac develops (Fig. 15).

It appears that the embryo sac frequently fails to develop and in this case the rest of the ovule grows normally for a while, but eventually the nucellus and integuments disappear and only the funicle remains, forming the flat papery sterile seed which is so often found in the fruit.

In the eight nucleate embryo sac, the synergidae take up their position before the antipodals group themselves at the base

of the sac (Fig. 18). The egg is small, but the secondary nuclei are very conspicuous and are usually surrounded by starch, which is more abundant in the later stages (Fig. 19).

Embryo Formation

The fully developed embryo sac does not persist long. The egg soon disappears, and the antipodals and synergids are the next to disintegrate. The secondary nuclei remain for some time, but they also disintegrate and form part of a darkly staining mass which eventually disappears (Fig. 20).

A particularly noticeable feature of this development is that there is no formation of endosperm tissue. On the other hand, the nucellar tissue increases considerably. The nucellus elongates and the chalazal end curves and becomes much broader. The embryo sac is ruptured and forms a long, irregular cavity down the centre reaching to the curved portion of the nucellus. The broken walls of neighbouring nucellar cells project loosely into the cavity.

The elongated cells of the nucellar cap are very conspicuous at this stage, their radial walls are slightly thickened and their contents stain very deeply. The first signs of nucellar embryo formation now occur. A cell below the nucellar cap, and bordering on the embryo sac cavity, enlarges and rounds off; its wall thickens and its contents divides twice, at right angles, forming the first four cells of the proembryo. Further division takes place and finally the proembryo ruptures the wall of the parent cell. Several neighbouring nucellar cells become active in the same way, and soon the embryo sac cavity is filled by the developing proembryos (Figs. 21-23). As the competition becomes more severe, the younger ones are destroyed, and only one or perhaps two embryos reach maturity.

Nucellar embryony also occurs in *O. vulgaris*, Ganong (1898), and *O. Rafinesquii*, Hull (1895) and apparently also in *O. ficus indica* and *O. leucantha*, Montemartini (1899), while polyembryony has been found in all the above as well as in *O. tortispina* and *O. glaucophylla*, Braun (1860) (ex Schnarf, 1929: 485).

In considering the cause of nucellar embryo formation, the development in *O. aurantiaca* is of particular interest, since it presents two unusual features, one of which does not appear to have been recorded before.

In the first case there is no fertilisation. In all the material I examined I could find no trace of pollen tubes either in the gynaecium or in the ovule. Numerous experiments in cross pollination and self pollination were made on plants growing in the veld at Uitenhage, but they failed to produce any sign of germinating pollen grains. Attempts to secure artificial germination in sugar solutions were also unsuccessful. According to Ganong, pollen tubes were found in the micropylar region of the nucellus of *O. vulgaris*. From his figures, these pollen tubes appear to be very similar to the elongated nucellar cap cells of *O. aurantiaca*.

The second unusual feature, and one for which I can find no parallel case, is the lack of endosperm formation. When adventitious embryo development is independent of fertilisation, it still appears to be dependent on endosperm formation, for it is usually stated that, at the time adventitious embryos begin to form, endosperm development is already taking place. Schnarf (1928: 470). *O. aurantiaca* appears to be the first recorded case in which adventitious embryo formation takes place without fertilisation or the development of endosperm, and thus three types of adventitious embryo formation may be distinguished.

1. Adventitious embryo formation dependent on fertilisation and endosperm development, e.g. *Citrus aurantium*, etc.
2. Adventitious embryo formation dependent on endosperm development and not on fertilisation, e.g. *Caelebogyne ilicifolia*, etc.
3. Adventitious embryo formation dependent neither on fertilisation nor on endosperm development, e.g. *O. aurantiaca*.

According to Ganong (1898), *O. vulgaris* would fall into the first class; but if it were found that what he considered to be pollen tubes were actually nucellar cap cells, such as occur in *O. aurantiaca*, then *O. vulgaris* would come into the second class for, in common with other members of the *Cactaceae*, its endosperm is formed by free nuclear division. Schnarf (1928: 373).

With respect to the cause of nucellar embryo formation, Haberlandt's theory (1922) that the so-called necrohormones, formed from damaged or injured tissue, cause callus which precedes adventitious embryo formation, may advantageously be considered here. In *O. aurantiaca*, there is injured tissue caused by the rupture of the embryo sac due to the elongation of the nucellus, and, as Haberlandt pointed out for *Funkia ovata*, it is always in the neighbourhood of injured cells that adventitious embryo formation takes place. Since the majority of plants that show adventitious embryony are cultivated plants or plants growing in conditions different from those of their original habitat, it has been suggested that cell degeneration, which finally causes adventitious embryony, is influenced by adverse cultural conditions. Schnarf (1928: 472). It is a legitimate speculation whether the climatic conditions of South Africa have influenced the embryony of *O. aurantiaca* to this extent.

The Seed.

In Jointed Cactus, lack of viable seed is due to two factors. The first, failure of the dyad to develop, was mentioned above, the second failure occurs when the adventitious embryos are still quite young. The nucellus continues to grow even after the embryo initials are formed. At the same time the funicle is transformed into a hard lignified coat so that there is a sudden transition in the chalazal region between the soft nucellus and

the hard funicle. The curving and elongation of the nucellus probably places considerable strain on this region. In many cases, seeds at this stage showed that the vascular strand passing into the chalaza was broken (Fig. 21). Thus, although the funicle might continue to develop, the nucellus would be cut off from further nourishment and consequently the adventitious embryos, being entirely dependent on the nucellus, would fail to develop. It is suggested that this is probably the manner in which the second type of sterile seed develops.

The three types of seed can, with a little practice, be immediately distinguished by the mucilaginous mass which surrounds them. This mucilaginous mass, which consists of long soft hairs and large mucilaginous cells, develops from the outermost layers of the funicle.

The first type of sterile seed, which is thin and flat, has hardly any surrounding mass of mucilaginous tissue. The second type of sterile seed, which is somewhat swollen and has a hard funicle, is fairly plentifully surrounded by soft tissue which has rather a white woolly appearance and does not contain much mucilage. The soft tissue of viable seed is green and translucent and contains large quantities of mucilage.

Viable seed is about 4 mm. long and 3 mm. broad. The hard funicle cannot be easily cut or cracked. It surrounds the embryo completely and blocks its exit by forming a loop over the micropyle. (Figs. 4, 21, 24).

The embryo is well developed and fills the seed, and only a very small portion of the nucellus remains. The cotyledons are large and the radicle has a conspicuous cap to its growing point (Fig. 24). The cells of the embryo are filled with granules which give a protein reaction with Millon's Reagent. The outer and inner integuments remain as thin papery coverings of the embryo.

Sometimes two adventitious embryos reach maturity.

Amount of Viable Seed.

The seed takes some time to mature and the ripe fruit of February flowers cannot be found until July. Viable seed occurs rarely, and in most cases fruit contains the two types of sterile seed mentioned above, sometimes the one sometimes the other predominating. It is not possible to tell from the external appearance of the fruit whether it contains viable seed or not. The following table shows the proportion of viable seed to fruit:

Place of collection.	Time.	No. of fruits examined.	No. of viable seed.
Uitenhage	Feb. and April ...	780 ...	111
Uitenhage	July	1074 ...	66
Middle Drift (Alice) ...	August	1657 ...	2
Uitenhage	Sept. and Oct. ...	1557 ...	69
	Total ...	5068 ...	248

Since there are between 80 to 200 ovules in each fruit, the amount of viable seed is very low indeed. In general it may be considered that there is about *1 viable seed* to every *20 fruits*, or, taking only the Uitenhage fruit in which viable seed occurred more frequently, about *1 seed to 14 fruits.*

Germination Tests.

Because of the small number of viable seed, regulation germination tests could not be carried out. The methods employed, however, were similar to those recommended in the United States. Rules for Seed Testing (1928).

The well-developed embryo and the structure of the seed coat indicated that it was probably mechanical resistance to the expansion of the embryo which caused the prolonged dormancy which had been found to exist by preliminary germination tests. (Third case of dormancy—Crocker, 1916). Therefore only methods likely to break down this mechanical resistance were employed. In all experiments, seeds were kept at a uniform temperature of 24°C. When treated with acid, seed were soaked in 50 per cent. H_2SO_4 for 15 minutes then thoroughly washed before being tested. Unless otherwise stated, the mucilaginous mass was always removed before seeds were tested. When the seed coat was cut, the micropylar end of the funicle was removed so as to expose the radicle.

Test 1.

Experiment No.	No. of seeds set.	Treatment.	Germination after Days.	Total.	% Total Germ.
			1 2 3 4 5 6 7 8 9 — 37		
1	21	H_2SO_4 and cuts	- 2 1 - 6 - - - - - -	9	43
2	25	H_2SO_4 . . .	- - - - - - - - - - —	-	-
3	25	90°C water for 3 mins.	- - - - - - - - - - —	-	-
4	25	No treatment ..	- - - - - - - - - - —	-	-

Three of the nine seed which germinated in Experiment 1 had double embryos. Seeds of Experiments 2, 3 and 4 were used again as follows:—

Test 2.

Experiment No.	No. set.	Treatment.	Germination after Days.		Total.	%
			1 2 3 4 5 6 7	—		
2(b)	18	Seed coat cut ...	2 3 3 - 3 2 -	—	13	72
3(b)	18	Flame for 8 secs.	- - - - - - -	—	-	-
4(b)	18	No treatment ...	- - - - - - -	—	-	-

Of the 13 which germinated two gave double embryos, both of which matured.

From these experiments it may be concluded that mechanical obstruction by the funicle is the only cause of dormancy, since germination took place within 24 hours of this portion being removed.

Germination and the Seedling.

In searching for Jointed Cactus seedlings, I have had the valuable co-operation of Mr. E. du Toit, Chief Weeds Inspector of the Eastern Province. I can only report four cases of seedlings occurring in the veld, two found by Mr. E. du Toit and one by an overseer in the Middledrift area, and one collected by myself on the Uitenhage commonage. Germination in nature probably occurs as the result of accidental injury or at the end of a prolonged period when the funicle has rotted away.

Fig. 25a-c shows various stages in the development of artificially germinated seedlings. The stage where the seed coat is carried up on the tip of the cotyledons is reached within three or four days of the commencement of germination. When there is more than one embryo present in the seed, one seedling is usually in advance of the other and sometimes the second fails to mature. The cotyledons usually emerge quite easily from the seedcoat, but they may be held fast by it and then the seedling dies.

The cotyledons are ovate and about twice as long as they are broad. They are thick and succulent, green on top and reddish below. The first joint is globular and elongates only gradually. (Fig. 26). In Prickly Pear the cotyledons are ovate-lanceolate, about three or four times as long as they are broad. They are not very thick or succulent and are only slightly reddish on the under surface. The first joint is globular only in the very youngest stage, and elongates rapidly and is a cylinder when the first joint of a Jointed Cactus seedling of the same age is still gloublar.

SUMMARY.

1. A fully illustrated account of the development of the ovule of *O. aurantiaca* shows how the funicle surrounds the rest of the ovule, even to the covering over of the micropyle. The term circinotropous is suggested to describe this type of ovule.

2. A review of the literature on ovular structure in the genus *Opuntia* suggests that it is highly probable that this type of ovule is characteristic of the genus.

3. In other respects, the ovular structure is considered typical of the Centrospermae.

4. The development of the embryo sac is given. The eight nucleate bisporic embryo sac corresponds to the *Allium* type with the exception that it is the micropylar dyad cell which forms the embryo sac.

5. Adventitious embryos are formed from the nucellus without previous fertilisation or the formation of endosperm tissue.

This is thought to constitute a new type of adventitious embryony.

6. Viable seed and two types of sterile seed are described. It is suggested that failure of embryo sac formation and the breaking of the vascular supply in the chalazal region are respectively the causes of the two types of sterile seed.

7. The results of a limited number of germination tests are given. Dormancy is due to mechanical obstruction caused by the hard funicle covering the micropyle and blocking the exit of the embryo.

8. The seedling is described and compared with that of Prickly Pear. The lack of seedlings in the veld is commented upon. Polyembryony is recorded.

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ILLUSTRATIONS.

Scale lines are placed beside figures to which they refer.

Fig. 1.—Front view of ovule showing early stage of development. f, funicle; oi, outer integument; ii, inner integument; n, nucellus.

Figs. 2 and 3.—Longitudinal sections of ovule showing further stages of development.

Figs. 5, 6, 7, 8, 9.—Successive transverse sections of ovule showing how sides of funicle grow out and fuse with that part of the funicle opposite. v.s, vascular strand; i.-iv, compare with Fig. 4.

Fig. 10.—Sides of funicle fusing. Area corresponds to that marked in Fig. 8.

Fig. 4.—L.S. of mature ovule. f, funicle; h, hair zone; c, canal entrance; ch, chalaza; oi, outer integument; ii, inner integument; n, nucellus; m, micropyle; i-iv, are the parts corresponding to i-iv in Figs. 5-9.

Fig. 11.—L.S. of mature ovule. n.c, elongated nucellar cap cells.

Fig. 12.—L.S. of nucellus showing archesporial cell.

Fig. 13.—Cover cell, cc; and megaspore mother cell mg. mc.

Fig. 14.—Dyad.

Fig. 15.—Twin dyads.

Fig. 16.—Row of three cells. m.d, micropylar dyad cell; msp, two megaspores.

Fig. 17.—Development of micropylar dyad cell which forms embryo sac.

Fig. 18.—Eight nucleate embryo sac. sy, synergidae; e, egg; sc, secondary nuclei; a.n, antipodal nuclei.

Fig. 19.—First stages of disintegration of embryo sac. St, starch grain.

Fig. 20.—Last stage of disintegration of embryo sac.

Fig. 21.—L.S. of seed at first stage of embryo development. f, lignified funicle; n, elongated nucellus; n.c, nucellar cap cells; e.c, cavity formed by elongation of ruptured embryo sac; em, adven-

titious embryos; ch, break in region of chalaza; mm, mucilaginous tissue forming on outside of funicle; tt, attachment to ovary.

Fig. 22.—Early stage in development of nucellar embryos. dr, broken nucellar tissue projecting into embryo sac cavity; pr, proembryos.

Fig. 23.—Later stage in development of embryos, two more advanced than the rest.

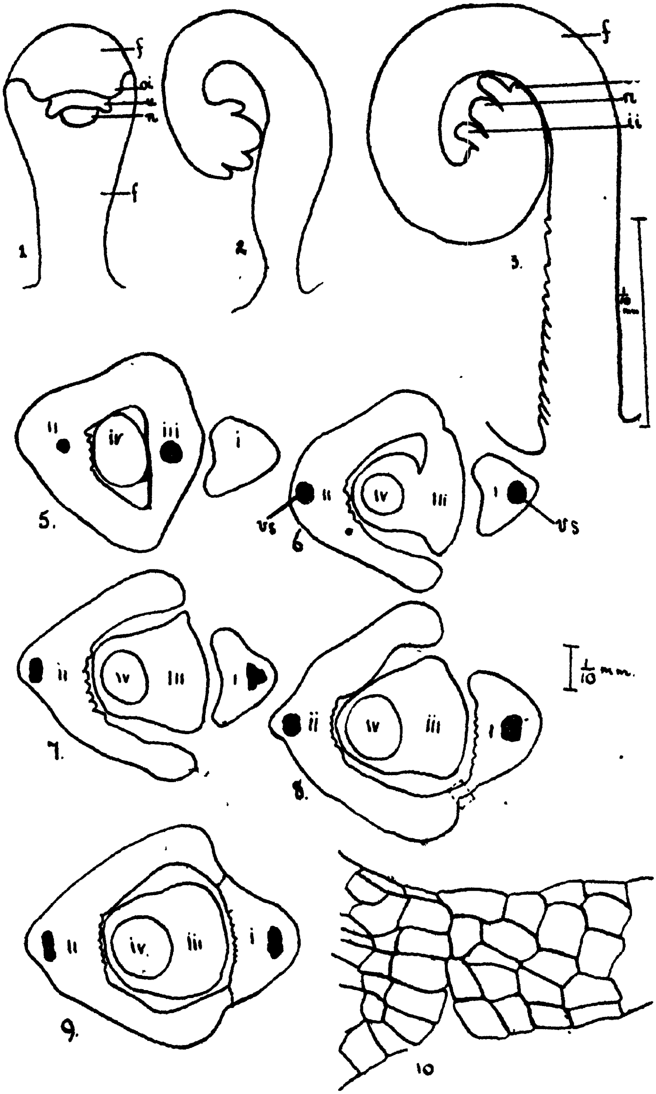
Fig. 24.—L.S. of Seed. nr, remains of nucellus; cc, cotyledons; r, radicle; roi, remains of outer integument; rii, remains of inner integument; m, micropyle; f, lignified funicle; vs, vascular strand. The width of the outer and inner integuments has been exaggerated for the sake of clarity.

Fig. 25.—Germination of Seed. (a) First stage. f, funicle; hy, hypocotyl; h, hairs; r, radicle.

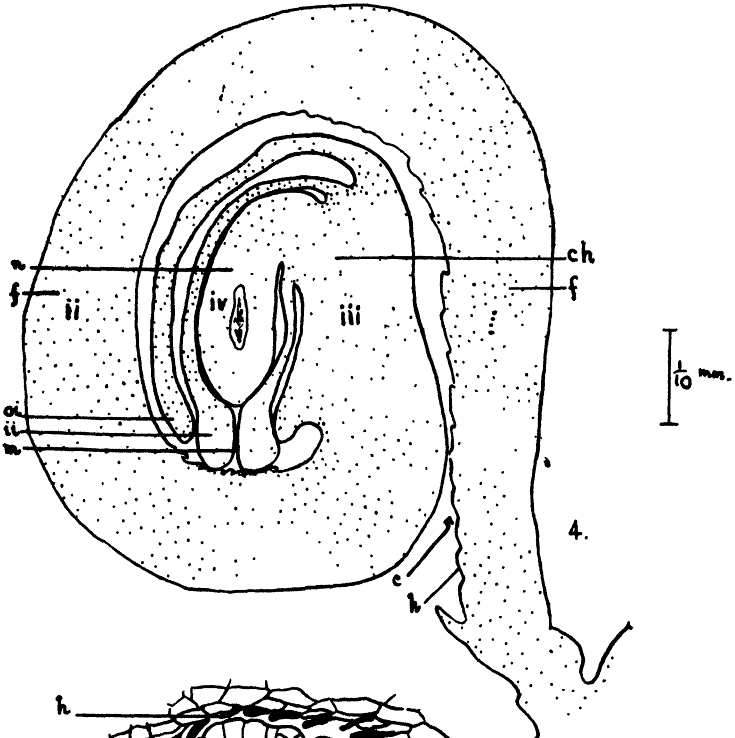
(b) Seedcoat carried up by cotyledons.

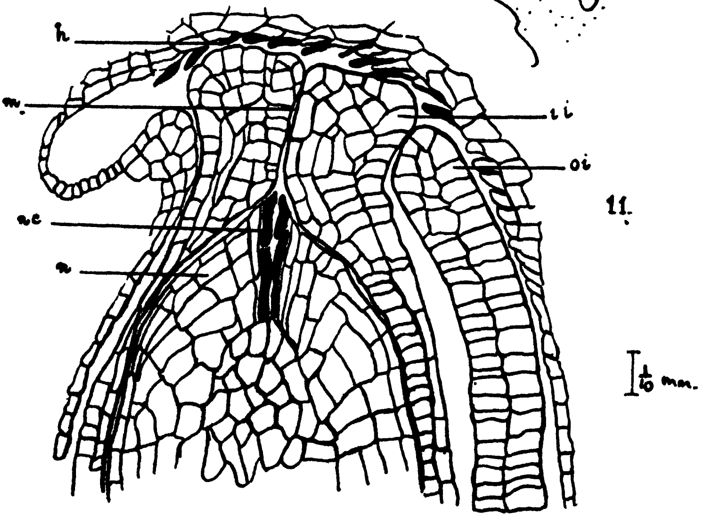
(c) Two embryo that have developed from one seed.

Fig. 26.—Seedling. r, root; hy hypocotyl; cc, cotyledon; j, globular joint; ar, areole bearing trichomes and thorns.

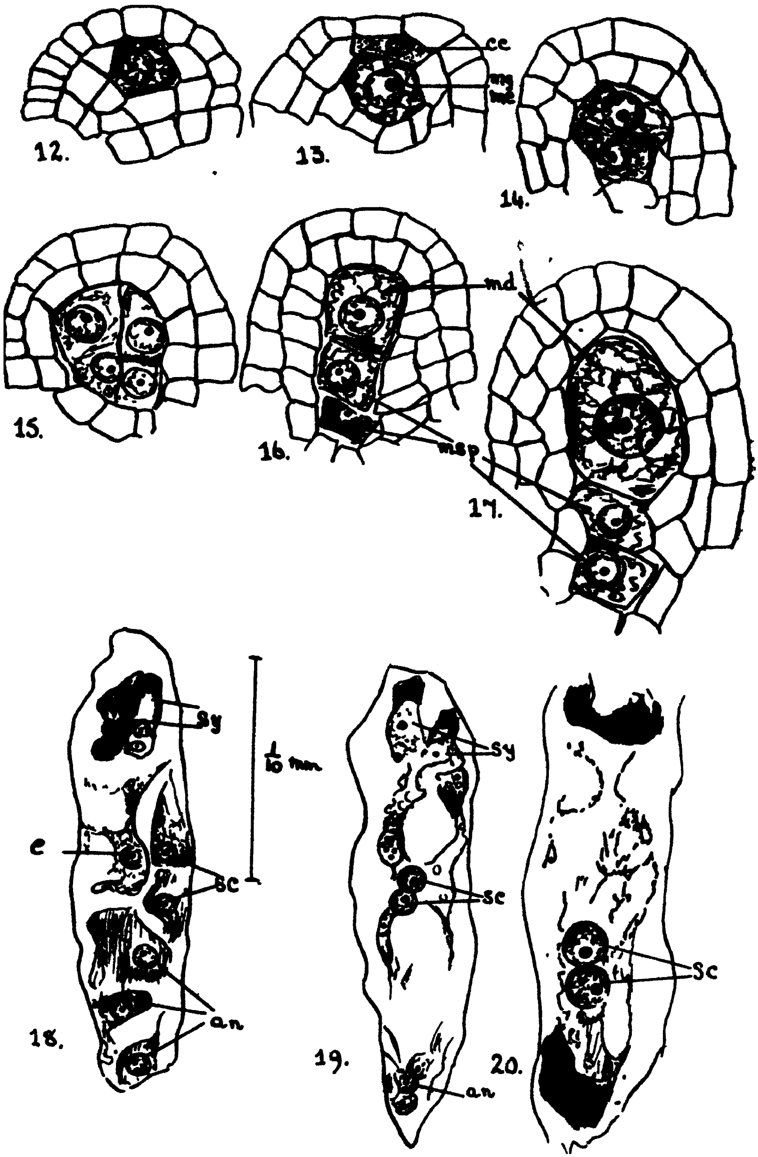


Figs. 1, 2, 3 and 5 to 10.

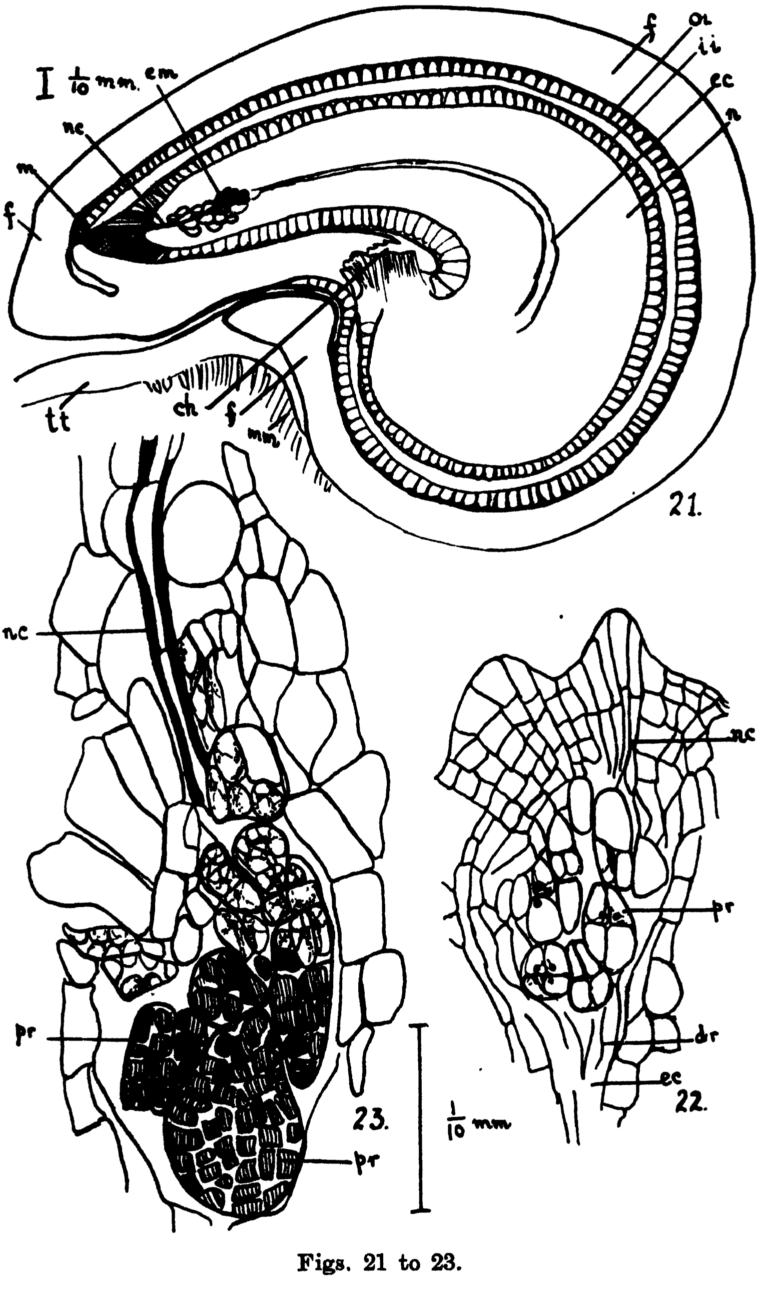




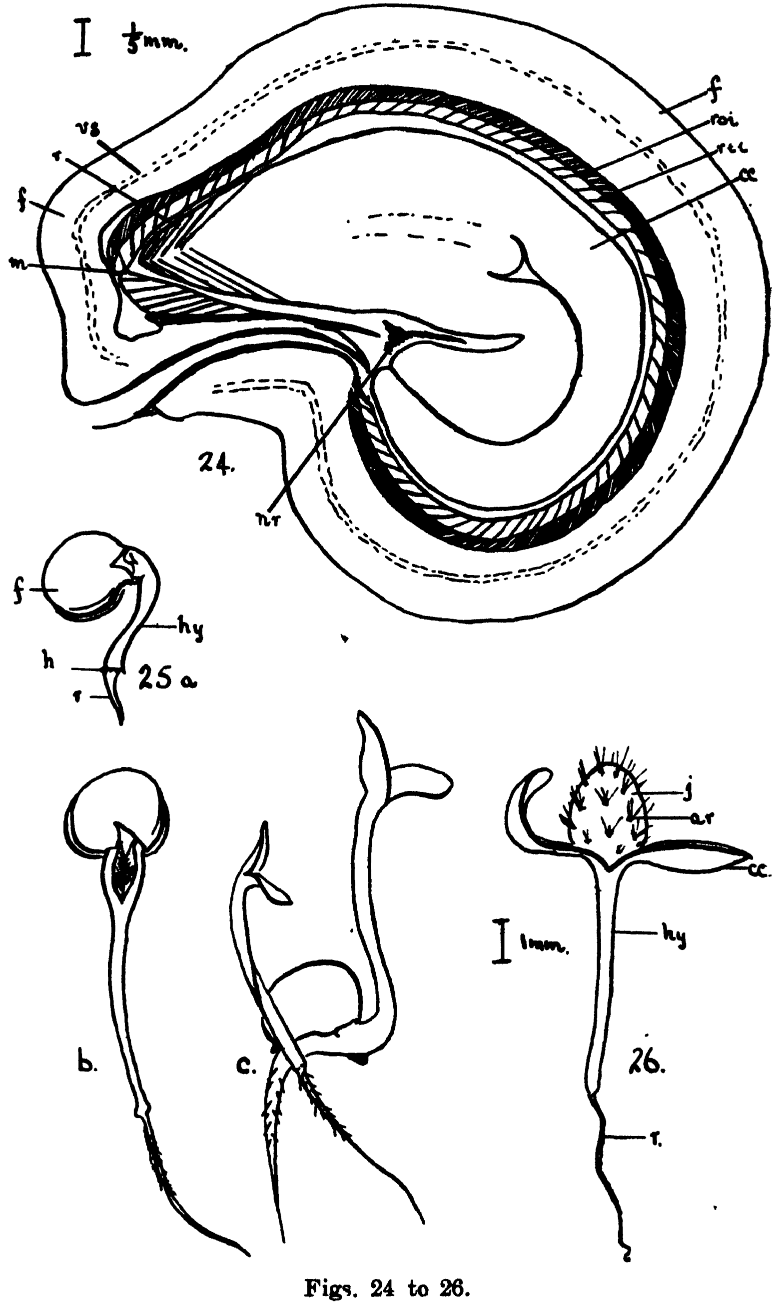
Figs. 4 and 11.



Figs. 12 to 20.



Figs. 21 to 23.



Figs. 24 to 26.

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GERMINATION OF KARROO BUSH SEEDS. PART II

BY

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Some years ago I (Henrici, 1935) drew attention to the generally small number of seeds of Karroo bushes that germinated to the long period of after ripening and to the influence of different constant temperatures. It was sursprising that only a few species showed an actual increased germination in light compared to germination in darkness. It was decided to test this point on a larger scale and with more species. This was done in several series, lasting from July, 1934 to May, 1936. Seeds were exposed at 20° or 30° in light or darkness, in Zürich pattern dishes which were kept open in the case of exposure in light and covered in case of exposure in darkness. Every month fresh seeds were exposed, the seeds kept on for three to four months. Mostly 100 seeds were taken, in a few cases when seeds were scarce only 20 for each month. The method was the same as previously described.

As temperature was more important than light, it was thought possible to increase germination by employing alternate instead of constant temperature. Seeds kept in darkness were subjected for 20 hours at 20°C and for four hours at 3-4°C in a refrigerator, or for 20 hours at 30° and for four hours at 3-4°C. Not all species could be exposed at 30°C as the Hearson incubator for 30° was too small. The experiments lasted from September, 1936 to August, 1937. Each month 100 seeds of every species were exposed to the alternate temperatures and 100 were used as control at 20°C and at 30°C. Experiments were also continued to see whether the rhyhm which was observed in the yearly germination curve of many Karroo bushes under constant temperature, would be continued over a number of years.

The following species were used for experiments to test the influence of light (the time of harvest is given in brackets):— *Salsola glabrescens* (April, 1935), *Atriplex capensis* (Nov., 1934), *Atriplex Mulleri*, *Tetragonia arbuscula* (Oct., 1934), *Hyperstelis verrucosa* (April, 1934), *Sutherlandia humilis* (July, 1934), *Lotononis divaricata* (Nov., 1934), *Hermannia linearifolia* (1935), *Helichrysum pentzioides* (Nov., 1934), *Aster filifolius* (1933), *Euryops multifidus* (July, 1934), *Tripteris pachypteris* (Jan., 1934), *Osteospermum muricatum* (Jan., 1934), *Pegolettia polygalaefolia* (July, 1934), *Pentzia incana* (March, 1934), *Pteronia glauca* (July, 1934).

The same species were used for the tests on alternate temperatures, that is to say:—

Tetragonia (March, 1935), *Pteronia glauca* (1935), *Aster filifolius* (1934), *Helichrysum* (1936), *Atriplex capensis* (March, 1936), *Salsola glabrescens* (March, 1936), *Hyperstelis* (1936), *Pegolettia* (June, 1936), *Tripteris leptoloba* (1935), *Tripteris pachypteris* (1935), *Phymaspermum parvifolium* (1935), *Pentzia incana* (1935).

RESULTS.

(1) *Experiments at constant temperature extended over some years.*

Seeds of one particular harvest subjected over a number of years to a constant temperature and controlled light, do not all behave in the same way. Some like *Pentzia sphaerocephala* and *Tripteris leptoloba* abandon the peak curve and keep on a fairly regular percentage of germination after some time, regardless of the season. But most of the seeds showed a peak throughout all the years of observation.

(2) *Experiments at different constant temperatures.*

(Tables 1 and 2. Series 1934/36 and 1936/37.)

For all these tests the seeds were exposed in the dark at 20°C and 30°C. The series for *Euryops multifidus* and for *Atriplex Mulleri* (harvested 1934, exposed 1934/36), confirm the idea previously expressed (Henrici, 1935) that germination is better at the lower temperature. Table 1 gives the result of the 1,200 seeds exposed in the series 1936/37.

TABLE 1.

Germination at different temperatures.

Of 1,200 seeds germinated:

	At 20°C.	At 30°C.	Peak at 20°C. in Month	Percentage of Germination at peak time at 20°C.	Peak at 30°C. in Month	Percentage of Germination at peak time at 30°C.
Pentzia incana -	224	79	April	38	April	38
Phymaspermum parvifolium -	559	379	Nov.	73	April	40
Tripteris pachypteris -	975	877	Sept.	97	Nov.	97
Tripteris leptoloba -	1,126	885	Sept. April	100	Dec.	95
Hyperstelis verrucosa -	121	40	March	34	March	18
Salsola glabrescens	3	2	Very bad harvest			
Atriplex capensis -	985	926	July	92	March	95
Tetragonia arbuscula -	380	308	Sept.	94	Nov.	77

Incidentally it should be noticed that the figures for germination of the 1,200 seeds can only be compared within the same harvest. The harvest of *Salsola* (March, 1935) or *Tetragonia* (Oct., 1934 or Feb., 1934), gave a much higher percentage of germinations, whilst other harvests of *Phymaspermum* gave lower germination.

The germination for the different species varies a lot, as well as the germination of the same species at the two temperatures. The maximum germination does not often occur at the same time of the year for both temperatures, generally it is later in the season for the higher temperature. The percentage germination at the peak time may also be altered, generally it is lower at 30°C.

The figures in Table 1 are the final figures of germination regardless of the time the seeds took to germinate. Few species so far investigated, germinate quickly, even if the time of after ripening has elapsed. Thus, as in the previous investigation, the germination within a month was calculated separately and compared with the total germination which could extend to three months. It may be asked whether the different temperatures influence the period of germination. Except for a few species, *Atriplex capensis* and *Hypertelis verrucosa*, the delay in germination is not pronounced. It is smaller at 20°C than at 30°C. Actually at 20°C only one to two per cent. of most seeds do not germinate within a month. At 30°C the retardation is considerably longer, up to 30 per cent. of certain seeds do not germinate within a month.

3. *Experiments with alternate temperatures. Tables 2, 3, 4.*

The effect of alternate temperature is not uniform for the different seeds. Even if a stimulating influence can be noticed for the particular species, the influence is not the same in the different months, there may be times when no increased or even decreased germination takes place. All experiments were done in the dark. The stimulating influence of the alternate temperatures is not necessarily the same at 20°C as at 30°C, as can be seen from Table 2.

Plants which germinate very well in constant temperature, cannot be expected to germinate *still better* under alternate temperature, as e.g. the two species of *Tripteris*. Very poor harvests like that of *Salsola glabrescens* or *Helichrysum pentzioides* cannot be improved by alternate temperature. There are the species with medium germination power which can benefit the most.

TABLE 2.

In the 12 months stimulating influence of alternate temperature was observed:

	At 20°C.		At 30°C.	
	Times	Months where no stimulation took place	Times	Months where no stimulation took place
Tetragonia arbuscula ...	10	Sept., Jan.	9	Nov., June, July
Atriplex capensis	6	Sept. to Nov. April to May	8	Sept., Mar,, April
Salsola glabrescens	0		0	Bad germination
Hyperstelis verrucosa ...	0	Whole year	8	June to Aug.
Pteronia glauca	10	Oct., April		
Aster filifolius	7	Dec., March to August		
Helichrysum pentzioides ...	0			Bad germination
Pegolettia polygalaefolia ...	5	Oct., April		
Tripteris leptoloba	3	May, June	2	May and Aug.
Tripteris pachypteris ...	2	June	4	Nov., April
Phymaspermum parvifolium	4	Sept., Nov., Jan., June	2	Sept. to Mar., April, June, August
Pentzia incana forma ...	9		12	

TABLE 3.

Total germination of 1,200 seeds in a year at constant and alternate temperature.

	20° constant	20° alternate	30° constant	30° alternate
Tetragonia arbuscula ...	380	484	308	433
Atriplex capensis	985	1,070	926	1,007
Salsola glabrescens ...	3	6	2	4
Hyperstelis verrucosa ...	121	93	40	65
Pteronia glauca	152	276	—	—
Helichrysum pentzioides ...	3	1	—	—
Aster filifolius	4	26	—	—
Pegolettia polygalaefolia...	35	90	—	—
Tripteris leptoloba ...	1,126	1,062	882	961
Tripteris pachypteris ...	975	1,035	877	884
Phymaspermum parvifolium	559	538	379	229
Pentzia incana forma ...	224	353	79	219

At 20° alternate temperatures favour germination of *Tetragonia*, *Atriplex capensis*, *Salsola glabrescens*, *Pteronia glauca*, *Aster filifolius*, *Pegolettia polygalaefolia*, *Tripteris pachypteris* and *Pentzia incana*, if the total number of germinated seeds are counted. At 30°C the influence of the daily four hours refrigerator is generally greater: *Tetragonia*, *Atriplex*, *Salsola*, *Hyperstelis verrucosa*, both species of *Tripteris* and *Pentzia incana* benefit. As has been pointed out the influence is small for seeds that germinate well by themselves. The refrigerator treatment decreases at 20°C and 30°C the germination of *Phymaspermum*, and at 20° of *Helichrysum* and *Hyperstelis verrucosa*.

With regard to the period of germination (Table 4) in nearly all cases (except *Atriplex capensis*) the daily four hours cold temperature prolongated it. That is to say, that the seeds germinated slower and there were more seeds which took more than one month to germinate. The retardation is more marked at 30°C than at 20°C.

TABLE 4.

Delayed Germination of 1,200 Seeds.

	20°C	20°C alternate	30°C	30°C alternate
Tetragonia arbuscula ..	9	17	—	11
Atriplex capensis	198	113	257	145
Hyperstelis verrucosa ...	13	5	11	13
Pteronia glauca	0	20	—	—
Aster filifolius	3	9	—	—
Pegolettia polygalaefolia ..	0	4	—	—
Tripteris leptoloba ...	4	15	12	59
Tripteris pachypteris ...	10	57	57	92
Phymaspermum parvifolium	8	14	10	18
Pentzia incana	9	31	16	50

It has been pointed out that stimulated germination for the single species varies in the different months. The question arises whether there are definite times when the alternate temperature has no stimulating influence and other periods when it has its maximum effect. From Table 2 it is obvious that the months when no stimulation takes place are not the same for 20°C as for 30°C. For several species there is the tendency to show no stimulation at 20°C at the time when the maximum germination takes place, e.g. *Pentzia incana*, both species of *Tripteris* and *Atriplex capensis*. On the other hand for *Pegolettia* and *Aster filifolius* the stimulating effect of alternate temperature also occurs at the peak time. It is impossible to find an explanation for this different behaviour; it has to be accepted that the various species have different requirements for germination; and again it has to be remembered that species which have a high percentage of germination, often fail to show an effect of a stimulans. *Pegolettia* and *Aster filifolius* are plants which generally germinate

very badly, all the harvests which have been tested since 1934 showed very poor results. *Helichrysum pentzioides* and *Salsola glabrescens* which germinate very badly in the present series, had good harvests before and after, and it is possible that a better harvest would have shown a different result. For seeds which have a percentage of 90 to 100 per cent. and whose germination shows little of a stimulating effect by the alternate temperature, an influence can be expected on the *period* of germination, one would think a *priori* of a shortened period. But it is obvious from Table 4 that this is not the case.

On the contrary the two species of *Tripteris* show a very distinct delayed germination with both alternate temperatures. *Atriplex capensis*, however, has less delayed germinations at the alternate temperatures than at the constant temperatures.

4. *Experiments in diffuse light at constant temperatures. Tables 5 and 6.*

There are two series of these experiments. The results of series I, carried out between April, 1935 and April, 1936 at 20°C, are tabulated in Table 5. One hundred seeds of each species were exposed in open and 100 seeds in closed Zürich pattern dishes in a Hearson germinator (light) or Hearson incubator (dark).

In the second series the 100 seeds are exposed in the germinator at 20°C between July, 1934 and April, 1936, that is to say in light. Whilst the first series is intended to show the differences between the seeds in the dark and in diffuse light, series II should demonstrate the general trend of the germination in light, whether the same peak curve is adhered to as formerly described, etc. *Tetragonia arbuscula* was studied with controls in the dark, different harvests were used for three series between 1934 and 1936, showing very clearly the effect of after ripening.

Peak curves are also observed in light, if only for the first year. For *Tripteris pachypteris* the first year there is a sharp peak in spring, the second year a regular excellent germination extended over several months (between 90 and 100 per cent. germination. For some other plants (*Hermannia linearifolia, Osteospermum muricatum Sutherlandia microphylla*) there are one-peak curves, for *Pentzia incana, Pegolettia polygalaefolia* and *Tetragonia arbuscula* two-peak curves. It is striking that some plants have a peak in winter, which was not noticed before. *Pegolettia* and *Sutherlandia* are, however, plants which grow in winter. It seems that with the light treatment the peaks are found somewhat out of their usual time, and are generally a bit later.

For *Tripteris pachypteris, Pentzia incana, Pegolettia* and older *Tetragonia arbuscula* the period of germination is scarcely changed by the light, whilst *Hermannia linearifolia, Oosteospermum* and newer harvests of *Tetragonia* there is a good bit of delayed germination but nothing different from what has not been observed in the experiments carried out in the dark.

TABLE 5.

In light and darkness the following percentage germinated at 20°C:

Month	*Salsola glabrecens* Harvested April, 1935		*Atriplex capensis* Harvested March, 1934		*Hyperstelis verrucosa* Harvested 1935		*Lotononis divaricata* Harvested 1935		*Astev filifolius* Harvested 1933		*Helichrysum pentzoides* Harvested 1935		*Hermannia linearifolia* Harvested 1935		*Tetragonia arbuscula* Harvested Oct., 1934	
	Light	Darkness	Light	Darkness	Light	Darkness	Light	Darkness	Light	Darkness	Light	Darkness	Light	Darkness	Light	Darkness
April, 1935 ...	79	92	92	92	78	15	10	0	8	20	5	0	1	1	1 (5)	5
May	92	93	96	90	22	16	5	10	20	12	5	0	0	0	7 (8)	5 (6)
June	92	19	96	89	35	43	30	75	22	8	5	5	0	0	7 (11)	12 (15)
July	96	0	91	92	67	91	95	44	14	12	2	2	1	35	11	20
August	3	0	95	97	66	32	10	5	25	21	0	1	4	1	23	27 (28)
September ...	0	0	98	90	14	18	20	25	4	20	0	0	2	4	26 (27)	40 (46)
October	0	0	92	86	52	30	10	10	6	12	1	1	4	3	12	34 (35)
November ...	0	0	90	92	27	33	15	10	20	5	2	4	3	3	28 (29)	48
December ...	0	0	85	87	33	79	15	15	12	13	3	3	2	5	19 (21)	41 (49)
January, 1936 ...	0	0	99	84	20	74	15	10	3	1	16	1	0	0	38 (39)	33 (35)
February ...	0	0	85	59	16	23	0	10	5	5	1	1	3	3	20	51
March	0	0	92	81	41	26	5	10	5	4	1	0	1	1	8	34
April	—	—	—	—	—	—	—	—	—	—	—	—	—	—	30	27
Total of 1,200 seeds ...	362	204	1,111	1,039	471	480	230	224	144	139	41	18	21	56	230 [244]	393 [398]

1,300 seeds for *Tetragonia*, final germination in brackets.

TABLE 6

Germination in light at 20°C *100 seeds exposed every month*

Month	*Tripteris pachypterus*		*Hermannia linearifolia*		*Pentzia incana*		*Osteospermum muricatum*		*Sutherlandia microphylla*		*Pegolettia polygalaefolia*		*Pteronia glauca*		*Tetragonia arbuscula*		Same *Tetragonia arbuscula* in dark		*Tetragonia arbuscula* Harvest Oct 1934			
	Harvest Jan 1934		Harvest Jan 1934		Harvest Mar 1934		Harvest Jan 1934		Harvest July 1934		Harvest July 1934		Harvest July 1934		Harvest Feb 1934		Harvest Feb 1934					
	After 1 month	Total	After 1 month	Total	After 1 month	Total	After 1 month	Total	After 1 month	Total	After 1 month	Total	After 1 month	Total	After 1 month	Total	After 1 month	Total	After 1 month in light	Total in light	After 1 month in darkness	Total in darkness
July 1934		—	0	0	—	—	0	0	—		—	—	—	—	—	—	—	—	—	—	—	
August	83	83	0	0	—	—	0	0	12	12	0	0	—	—	—	—	—	—	—	—	—	—
September	73	73	0	0	—	—	0	0	15	15	16	16	—		3	3	92	92		—		—
October	73	73	10	20	—	—	50	55	10	10	12	12	—	—	35	35	99	99	—	—	—	—
November	62	62	5	20	—	—	25	35	13	13	10	10	—	—	30	30	49	49	—	—		—
December 1934	12	12	5	5	50	50	10	10	9	9	14	14	0	0	40	42	54	59		—		—
January 1935	57	66	0	0	65	65	0	0	6	6	28	28	0	0	48	55	51	54		—		—
February	41	44	0	0	45	45	0	20	10	10	21	21	0	0	57	59	62	62	0	0	1	5
March	41	41	5	5	35	35	35	45	13	13	2	2	0	0	41	42	71	74	—	—	—	—
April	23	23	0	0	25	25	30	35	1	4	15	15	0	0	70	73	81	86	1	5	5	5
May	27	27	0	0	35	35	75	75	10	10	44	44	0	0	62	65	77	79	7	8	5	6
June	36	36	0	0	45	45	85	85	2	2	50	50	0	0	64	66	77	77	7	11	12	15
July	17	17	2	2	40	40	50	55	31	[illegible]	20	30	0	0	52	53	71	71	11	11	20	20
August	95	95	3	5	25	25	70	70	6	6	34	35	0	0	68	69	78	78	23	23	27	28
September	98	98	0	0	55	60	40	40	3	4	23	25	0	0	60	60	76	76	26	27	40	46
October	88	88	1	1	40	40	45	50	9	10	6	6	0	0	63	63	79	80	12	12	31	35
November	93	93	2	2	20	20	40	40	13	13	45	45	0	0	75	75	69	69	28	29	48	48
December 1935	81	81	8	10	35	35	5	30	[illegible]	9	50	70	0	0	57	57	70	70	19	21	47	49
January 1936	97	97	1	2	35	35	30	35	5	11	22	22	0	0	24	25	60	60	18	19	33	35
February	87	87	1	2	20	20	10	30	18	24	1	1	0	0	42	43	55	55	20	51	20	51
March	93	93	1	2	15	15	30	30	[illegible]	9	1	1	0	0	17	17	38	38	8	34	8	34
April			—	—	—	—		—				—	—	—	14	14	37	37	30	30	27	27
May 1936	—	—		—	—	—	—	—		—			—		66	66	46	46	—	—	—	—
Total	1 290	1 299	44	76	585	590	630	740	213	232	425	427	0	0	988	1 022	1 229	1 298	230	301	336	398
Average percentage germinated	64	—	2	3 8	36	—	30	36	10 6	11 6	21	—	—	—	47	48	58	61	17	23	26	30

A parallel series of *Tripteris pachypteris* and *Hermannia linearifolia* was exposed at the same time in the dark at 30°C. The average monthly germination for *Tripteris* was 39 per cent. resp. 47 per cent. for total germinations, for *Hermannia* only 1½ resp. 3 per cent. Both species behaved in the same way. *Tripteris pachypteris* actually has a better germination and less delayed germinations in the light at 20°C, than in the dark at 30°C. *Hermannia* also germinated better in the light, but the period of germination in the dark was the same ratio in the dark as in the light. *Tetragonia* has a decided better germination in the dark than in the light. The discrepancy is the larger, the younger the harvest is.

Pteronia could not be forced to germinate.

Table 5 is the compilation of the seeds exposed in darkness or light at 20°C. Only *Salsola glabrescens* and *Helichrysum pentzioides* responded to the stimulating influence of light. For *Helichrysum* the fact was noted before, for *Salsola* an older harvest did not show this stimulation. Practically indifferent to the light conditions are *Hyperstelis verrucosa*, *Lotononis divaricata*, and *Aster filifolius*. *Atriplex capensis* germinates slightly better, *Hermannia linearifolia* and *Tetragonia* considerably better in darkness than in light. Formerly older harvests of *Hermannia* and *Atriplex capensis* showed indifference to illumination.

Resuming, it may be said there are only few species of those so far tested which show an increased germination by exposure in light. Even for these few species the age of the harvest seems to be of importance. Most species are indifferent as to germination in diffuse light or darkness. Few species like *Tetragonia* germinate always better in darkness regardless the age of the seeds.

Résumé.

Karroo bush seeds have been tested at different constant temperatures. They all germinated better at 20°C than at 30°C.

Alternate temperatures (20 hours 20°C and four hours 4°C or 20 hours 30°C and four hours 4°C) give different results for the various species. With few exceptions (*Phymaspermum parvifolium*) the alternate temperature 30°C plus low temperature is better than 30°C constant. At 20°C *Tripteris leptoloba*, *Phymaspermum parvifolium* and *Hyperstelis verrucosa* germinate better at constant temperature, than at alternate. Quite often alternate temperature, 20°C plus low temperature delays germination as compared with the constant temperature; an exception is however found in *Atriplex capensis* for which the period is shorter at alternate temperature.

The influence of light varies according to species and age of harvest. Only in a few cases a stimulating influence can be recorded.

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South African Journal of Science, *Vol. XXXVI, pp. 220-224, December, 1939.*

SURVIVAL OF FUNGI IN THE DIGESTIVE TRACT OF CATTLE

BY

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Read 6 July, 1939.

Introduction.

The possible survival of spores of *Diplodia zeae* (Schw)Lev. and *Gibberella saubinetii* (Mont) Sacc. after passage through cattle is of considerable importance, particularly in Rhodesia, but also in parts of the Union of South Africa. Dr. Hopkins has stated that " under Rhodesian conditions, it is not practicable for the average farmer to plough in his trash whilst the soil still contains sufficient moisture to enable the implements to work efficiently, because the maize stover is required to supplement the very meagre range feed which is available for his working cattle." Should the cattle feed on diseased stalks, and the spores survive passage through the animal, this might be a factor in spreading the disease. An experiment was therefore carried out to discover whether spores of *Diplodia* and *Gibberella* were viable after passage through the digestive tract of cattle.

This experiment had, as far as is known, not previously been carried out, though the idea had occurred to Van der Byl, in connection with the spores of *Diplodia* in 1915. He fed a mouse and a " Berg Canary " with spores of *Diplodia*, and found that on incubation, little or no germination of spores in the excreta took place.

Morwood (1929) considered that there was a possibility that the disease might be spread by feeding diseased material, but he did not test this out. Koehler and Holbert (1930) disregarded the possibility of survival, as, according to them, it was known that smut spores which had passed through the digestive tracts of cows and horses were no longer viable.

As far as is known nothing has been done in connection with the viability of *Gibberella* spores after passage through animals.

Spores of some other fungi are known to survive (see Ficke and Melchers, 1929; Leach and Mead, 1936).

Methods and Materials.

In February-March, 1939, facilities for conducting the present investigations were granted at the Onderstepoort laboratories,

through the courtesy of Dr. Groenewald. Three oxen, just under 4 years of age, were used. These animals had been fed for three years on a constant daily diet.

During the nine days of the experiment, the cattle were kept in stalls, and all the faeces collected daily. They were kept on their regular daily diet, with the addition, for the first five days, of oats infected either with *Diplodia* or *Gibberella*.

The feeding of the infected material was carried out daily for five days (22nd to 26th February) at 2 p.m. The rations of infected oats were as follows:—

Ox No. 6491: 20 grms. *Diplodia* infected oats.
6420: 20 grms. *Diplodia* infected oats.
6498: 40 grms. *Gibberella* infected oats.

As conidia of *Gibberella* developed very sparingly on the oats, a suspension of *Gibberella* spores in sterilised water was added to all the *Gibberella*-infected oats on the last three days of feeding, and on the last day a small section of maize stalk bearing perithecia was added to the *Gibberella* dose. The infected material was mixed thoroughly with the daily food. The oxen consumed the whole ration, and were apparently not affected by the addition to their diet.

Every day, from the 23rd of February to the 1st of March, the faeces of each animal were thoroughly mixed and a sample taken (about a litre of each). For the first two days spores could not be expected, but the samples were used for trying out methods of examination.

Results.

A.—Diplodia.

From the third to the seventh day *Diplodia* spores were easily seen when the manure was examined under the microscope. Pycnidia filled with spores were also present in the manure, and could be seen with the naked eye and removed by means of a spatula.

The viability of the *Diplodia* spores in the faeces of oxen Nos. 6491 and 6420 was tested as follows:—

(i) *In Turnip Extract.*

(a) On the third day pycnidia containing spores were placed on a concave slide in half-strength Turnip Extract, which was known to be a favourable medium for germination of spores of both *Diplodia* and *Gibberella*.

The slides were examined after 24 hours and again after 48 hours. None of the spores germinated, though spores from control pycnidia which had not passed through the animals germinated readily under similar conditions within 48 hours.

(b) From the faeces collected on the last day (1st March), spores were removed on the 3rd March by the following method: A small portion was shaken up with sterilised water and a drop

of the resultant infusion examined on a slide under the microscope. When spores were observed they were picked up by means of a glass tube drawn out to a very fine point, and transferred to one-fifth strength Turnip Extract in concave slides. None of the spores germinated.

(c) Turnip Extract (one-fifth strength) was poured into sterile petri dishes to a depth of about ½ cm. and a drop of the manure plus water mixture added. Examination under the microscope showed that each drop contained about 20 *Diplodia* spores. This was done on the 3rd, 4th, 6th and 7th days after feeding. A considerable amount of *Oidium* and *Rhizopus* and other fungi developed, but the *Diplodia* spores did not germinate.

As control, exactly the same experiment was set up, but fresh *Diplodia* spores were added. They germinated in some cases, but the germination tubes did not grow to any great length —probably as a result of the competition provided by *Rhizopus*, *Oidium*, protozoa and other micro-organisms which were present in the manure.

The fact that spores from the manure failed to germinate while the controls did, suggests that the spores were either killed or very much weakened.

There is the possibility that spores from the manure were prevented from germinating by other organisms from the manure. Other experiments with *Diplodia* (to be published later) have shown that the mycelium is apparently rather sensitive to the action of other micro-organisms, but the fact remains that control spores (Turnip Extract) germinated even though exposed to the action of the same micro-organisms as the *Diplodia* spores from the manure. The fact, however, that they made little growth after germination, suggests that conditions were not very favourable for further development, and if spores were only weakened, not killed, after passage through the animals, the adverse conditions might prevent germination.

(ii) *On Oatmeal Agar.*

On the 27th February (the fifth day), a small portion of the faeces collected the previously day was shaken up thoroughly in sterilised water and strained through a coarse cloth. The liquid was centrifuged; the resulting sediment was repeatedly shaken up with sterilised water and centrifuged again. Finally the sediment (containing numerous *Diplodia* spores) was spread out on oats plates. An *Oidium* was the only fungus making any growth —there was no sign whatsoever of growth of *Diplodia*.

On the sixth day pycnidia and spores found in the faeces collected the previous day were put out on oatmeal plates. No *Diplodia* developed.

(iii) *On Manure.*

On each day that the faeces were collected, a portion of each sample was examined to see whether colonies of *Diplodia* had

developed. The growth of unknown fungi and bacteria usually covered the surface of the manure but there was no trace of *Diplodia*.

This was not surprising since fresh control spores put on manure under the same conditions made no growth.

B.—Gibberella.

Repeated microscopical search through the faeces of the animal No. 6498 on every day on which spores were expected revealed no trace of the *Gibberella* conidia. Apart from examination of the faeces under the microscope, portions of the samples were shaken up with sterile water and treated as previously described. No spores were found.

This being the case, only methods (b) and (c) described for testing *Diplodia* spores could be carried out. There was no development of *Gibberella*, though various other fungi and bacteria grew, both on the manure and on the Turnip Extract. When a control experiment was carried out in the latter case on the same lines as in the case of *Diplodia*, the conidia could not be found after 24 hours. Mycelium made slight growth.

The results of these tests with *Gibberella* are not very satisfactory, since no trace of the conidia was found. As there were not as many spores in the infected material fed to the animals as in the case of *Diplodia*, it is possible that they were present in the manure though not observed. Since fresh conidia placed on the manure made no growth, it was hardly to be expected that *Gibberella*, even if it survived passage through the animal, would form colonies on the manure.

Conclusions.

It was found that *Diplodia* spores were not viable after passage through the digestive tracts of cattle and also did not germinate on fresh manure. In Turnip Extract, to which a little manure was added *Diplodia* spores germinated but did not develop any further.

In the case of *Gibberella* spores could not be recovered in the faeces. It is possible that the spores disintegrated during passage through the animal. *Gibberella*, like *Diplodia*, made no growth on fresh manure.

The results of experiments on the effect of manure on germination and growth (the results of which will be published at a later date) also indicated that the possibility that plants might become infected by *Diplodia* and *Gibberella* through manure is very remote.

The writer wishes to express her indebtedness to Miss E. E. Wijers, to the Rhodesian Government and Dr. J. C. F. Hopkins, and to Dr. J. W. Groenewald of the Onderstepoort Laboratories, whose support was invaluable.

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A PRELIMINARY REPORT ON METHODS OF THORN SCRUB ERADICATION

BY

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ABSTRACT.

A description of the various methods of eradication of thorn scrub by means of stumping, felling, felling and poisoning is described. The results of these treatments at different seasons show marked differences, best results being obtained with poisoning in summer and autumn.

An entirely new line of attack by means of applying paraffin to the stems of the trees is then discussed. It is pointed out that this can be done at about one-fifth of the cost of stumping and that, if it is not entirely successful in the experiments now being carried out, it opens up new lines of investigation which should lead to sound and cheap methods of scrub eradication.

South African Journal of Science, *Vol. XXXVI, pp. 225-226, December, 1939.*

AN INVESTIGATION OF THE EFFECT OF EUCALYPTS ON THE SOIL, AND OF THE TRANSPIRATION AND WATER-RELATIONS OF THESE PLANTS

BY

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Read 7 July, 1939.

Work has been done with regard to the effect of Eucalypts on the soil. This has involved a certain amount of field as well as laboratory work.

The field work was performed in the gum plantations on the Botanical Research Station, Frankenwald, near Johannesburg. For this purpose pits were dug in the gum plantations; in the adjacent grassveld, and also in an adjacent maize field—those in the maize field and the grassveld being for purposes of comparison.

Weekly determinations of the soil moisture were made, throughout the year, at levels of 3, 9, 15 and 21 inches. In addition to this, the soil was analysed chemically and physically.

A study was also made of the roots of these Eucalypts, by means of vertical quadrats.

The results of these investigations so far has shown that there is a very marked influence of the gums on the water content and ground cover of drier soils, but less marked in moist soils. Sheet erosion of the denuded soil is marked in these plantations. Results have shown, too, that there is a marked effect of gum roots on the phosphate-content of the soil immediately surrounding them, but the effect on the nitrogen content is not nearly so marked, although the nitrogen content of the soil in the gum plantations is lower than that of the adjacent grassveld and maize fields.

The roots of these gum trees also appear to have an effect on the maximum-water-retaining-capacity of the soils surrounding them.

For purposes of comparison, investigations are also being made in gum plantations and adjacent clumps of indigenous trees such as *Acacia caffra* and *Gymnosporia buxifolia*. Here again, results which have been obtained point to a very marked effect of the Eucalypt roots on the soil both with regard to the water-content and the phosphate-content, while the nitrogen content of the soil in which the Eucalypts grow is considerably lower than

that surrounding *Acacia caffra*, *Gymnosporia buxifolia* and in the adjacent grassveld. There is also a marked difference in the physical properties of the soil. The effects of the Eucalypts on potash content, if any, are being determined at the present moment.

In addition to the field work, the transpiration and growth of young gum trees has been thoroughly investigated, and much interesting and valuable information has been obtained with regard to transpiration and growth, and their correlation with temperature, light intensity, evaporation and other external factors. Experiments are also being carried out with the comparatively new torsion balance, as a changed method of measuring transpiration. Thus, instead of using pots containing whole plants, leaves or twigs can be weighed in fractions of minutes for plants with a high transpiration, such as Eucalypts. By this means, it is possible to ascertain within a short time the actual transpiration of the plant under any conditions. Much interesting information is expected from these experiments.

In addition to the work already mentioned, there is an experiment in which young gum trees have been grown in 50 lb. drums containing definite quantities of analysed soil for almost two years, with a view to finding out the nutrient requirements of these gums. The soil will be analysed for this purpose in December.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVI, pp. 227-235, December, 1939.*

PRELIMINARY STUDIES OF THE ROOT SYSTEMS OF *EUPHORBIA MAURETANICA, EUPHORBIA BURMANNI* AND *RUSCHIA MULTIFLORA* ON THE WORCESTER VELD RESERVE

BY

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AND

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With 8 Text Figures.

Read 7 July, 1939.

In continuation of the work on root studies of important plants of the Reserve (Scott and Van Breda), 1936, 1937 and 1938), three further species, viz., *Euphorbia mauretanica, E. Burmanni* and *Ruschia multiflora*, were studied during the past year.

PROCEDURE.

The method of using compressed air to uncover the roots, as described by Van Breda (1937), was again employed with satisfactory results.

LOCALITY: SOIL TYPES.

Euphorbia mauretanica is a common plant on the Reserve, but it occurs chiefly in dense communities on the dry, hard, stiff soils on the hills. It is unpalatable and, from the stock point of view, appears to have no economic value. It is a very important constituent of the veld, however, from the point of view of soil building. The living plant sheds annually many dry twigs which soon decompose, and many of the plants die off annually due to the root parasite *Hydnora africana*. (See Fig. 3D). The aerial parts of these dead shrubs crumble up to form humus on the soil and, where the communities are dense on hard ground, the soil is improved enough by the addition of humus from dead plants and decomposed dry twigs for more palatable plants to grow. This is well demonstrated where palatable plants such as *Pentzia incana-forma, Tripteris sinuata, Tetragonia fruticosa, Sutherlandia frutescens* and *Atriplex albicans* are found almost entirely in the dense communities of *Euphorbia mauretanica.*

It is rather interesting to note that *Hydnora africana* appears to attack *E. mauretanica* only when it is in dense communities. Although the host plant is unpalatable, if not poisonous, the parasite is greatly relished by both natives and stock.

Euphorbia Burmanni also grows abundantly on stiff, hard soils and seldom occurs in dense communities, but always seems fairly evenly distributed in the veld. It sheds many dry twigs annually, but they do not appear to decompose so rapidly or build up the soil in the same manner as *E. mauretanica.* It is very rarely attacked by *Hydnora africana*, and dead plants are seldom found.

Ruschia multiflora is well distributed over the whole Reserve and adapts itself readily to most soils. It is an exceptionally good drought-resisting plant, and is browsed at times when food is scarce.

ROOT STUDIES.

(a) *Euphorbia mauretanica* has a comparatively shallow root system with light brown, succulent and pliable roots which contain latex. It has no deep penetrating taproot. The main root usually breaks into major laterals within the surface foot of soil. (See Fig. 3A and 3D.) These usually number from four to six and may vary in size from 1 to 7½ cms., and usually extend out horizontally or obliquely to a distance of over 8 feet on every side, but rarely penetrate to a greater depth than 2 feet. Under dry conditions, however, the fine sub-laterals may penetrate to 4 feet.

In dry, stiff soil, the major laterals branch at irregular intervals depending chiefly on soil structure, but the sub-laterals are well equipped with small, threadlike branches, especially at the terminals. In loose soil with plenty of organic matter and fair mosture conditions, an extensive root system which ramifies throughout the surface foot is formed. (See Fig. 3A.)

The root system is very characteristic, especially as regards the branching of the fine rootlets. These do not branch and rebranch, but usually give off small, blunt, single side branches less than an inch long, running out at right angles from the rootlets often in clusters of four or more. The major roots are often well equipped with threadlike laterals which are well covered with fine root hairs to which fine particles of soil adhere as though they were sticky.

Fig. 3D shows a typical plant in normal arid conditions attacked by *Hydnora africana.* Fig. 3A shows the intense development of the root system under moister conditions in soil rich in organic matter.

(b) *Euphorbia Burmanni* has a root system very similar to that of *E. mauretanica*, except that the major roots seem to split more and taper at the terminals. The fine, threadlike branches, too, are not so blunt and thick as those of *E. mauretanica* and the roots are of a much darker colour.

Fig. 3F shows development of a plant under normal arid conditions, while Fig. 3B shows the development under moist conditions.

(c) *Ruschia multiflora* has an extensive root system which is light brown in colour and fairly soft and pliable. The main root usually sends out 3 to 6 major laterals within the surface foot. They usually travel out more or less parallel to the surface and, under arid conditions, may extend as far as 10 feet from the plant. They measure 2-3 cms. in diameter and are usually well branched. Some of the branches take a downward course and may penetrate to a depth of 14 feet. (See Fig. 6A.) There is generally no definite taproot below the depth of 1 foot, and roots penetrating deeper are usually branches of the original taproot or of the major laterals. The finer branches do not rebranch to any great extent, but have short side branches similar to those of *Euphorbia mauretanica*. The young branches in loose loam often have a thick bark, well covered with root hairs. When the soil is moderately soft, a massive root system may be developed (see Fig. B130) but, where the surface soil is soft and the subsoil very hard, all the roots may be distributed in the surface foot. Sometimes after a period of years, possibly due to the plant suffering from drought, it may send down deep penetrating roots much later. When this occurs, the branches in the surface layers often seem to die as the region of absorption is transferred to greater depths, and such plants seem to be almost independent of the rainfall. Under fair conditions the root systems develop very rapidly and plants, 14 months old, showed roots developed to a greater depth than 10 feet.

Figs. 6A, A11 and B130 show development of roots under normal conditions, and Fig. B44 shows the development of young plants under moist conditions.

Discussion.

The three species are important constituents of the veld on the Reserve, although none of them are of much value for stock feed. Both species of *Euphorbia*, which are large plants, have small root systems, while *Ruschia multiflora*, which is comparatively small but very drought resistant, has a very well developed and extensive root system. *Euphorbia mauretanica* seems to be important for the building up of soil.

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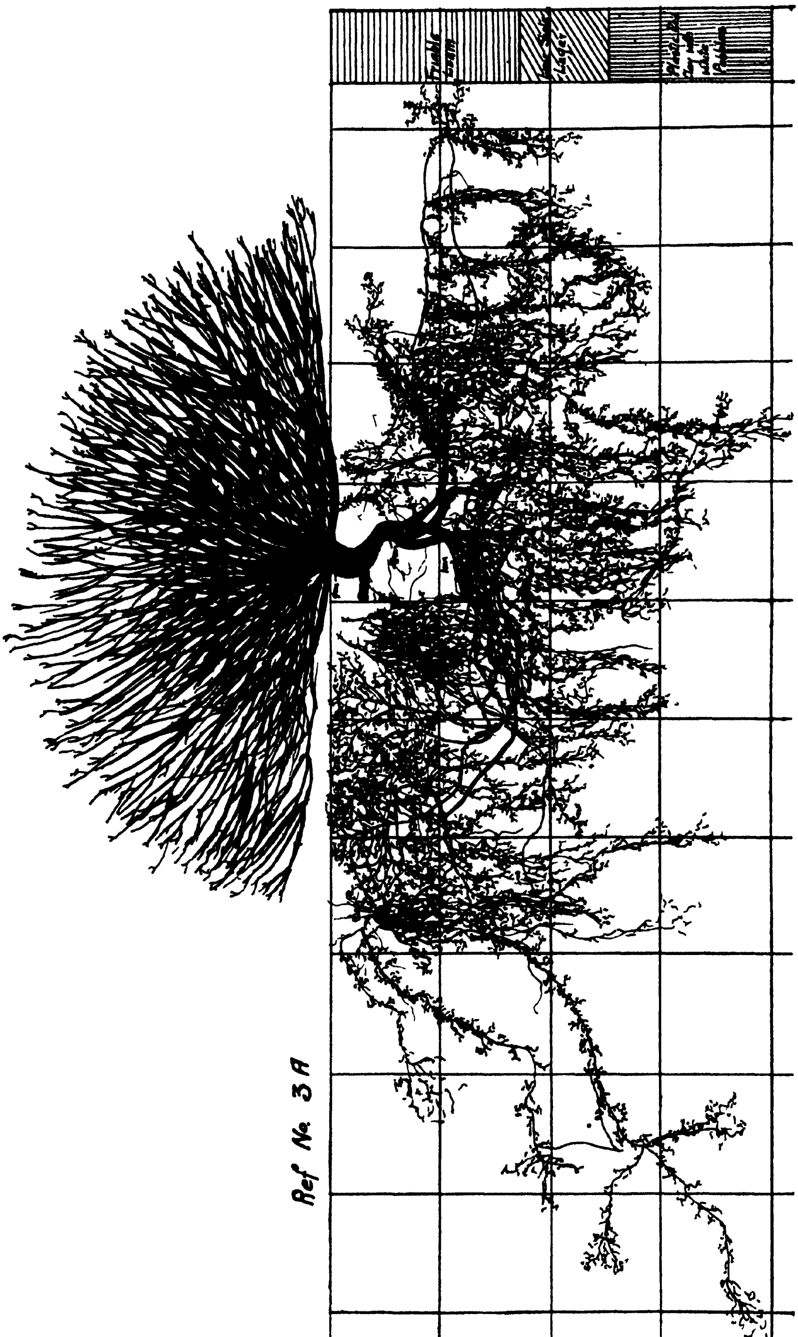
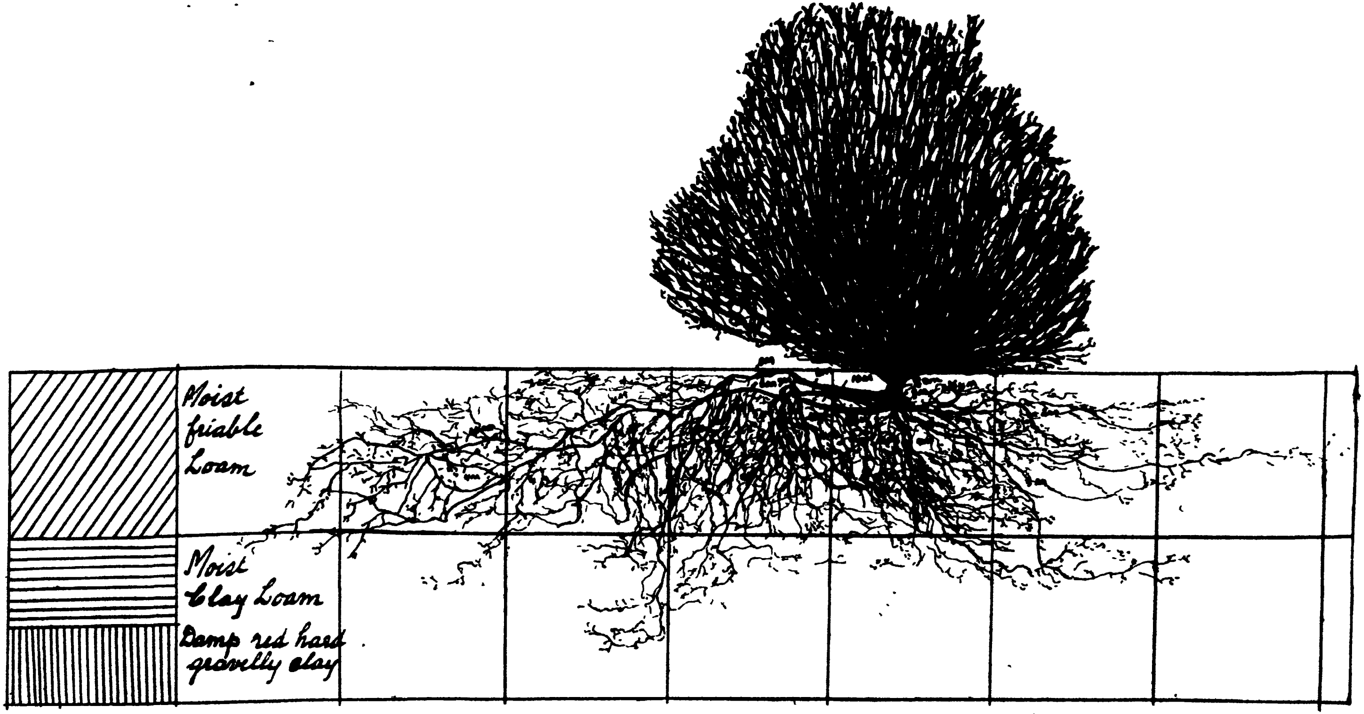
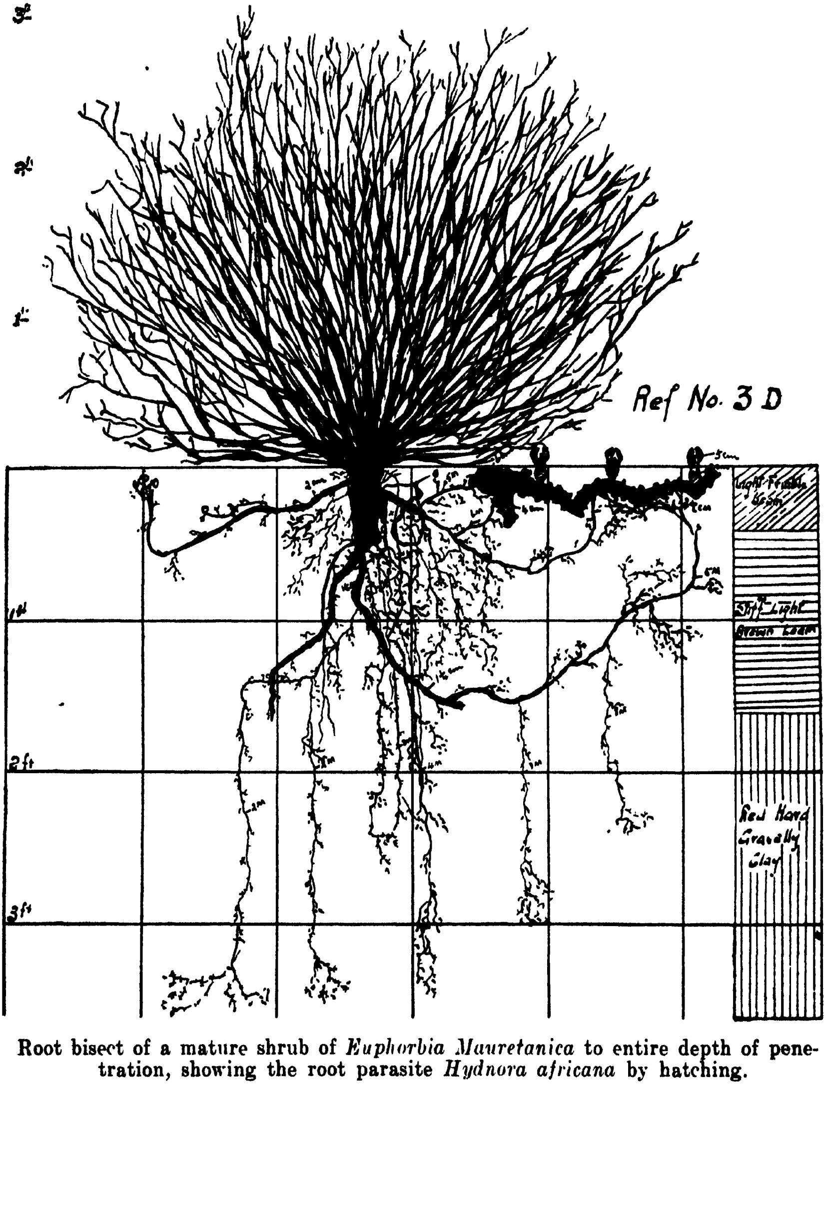


Root system bisect of mature "Melkbos," *Euphorbia mauretanica*, to entire depth of penetration.

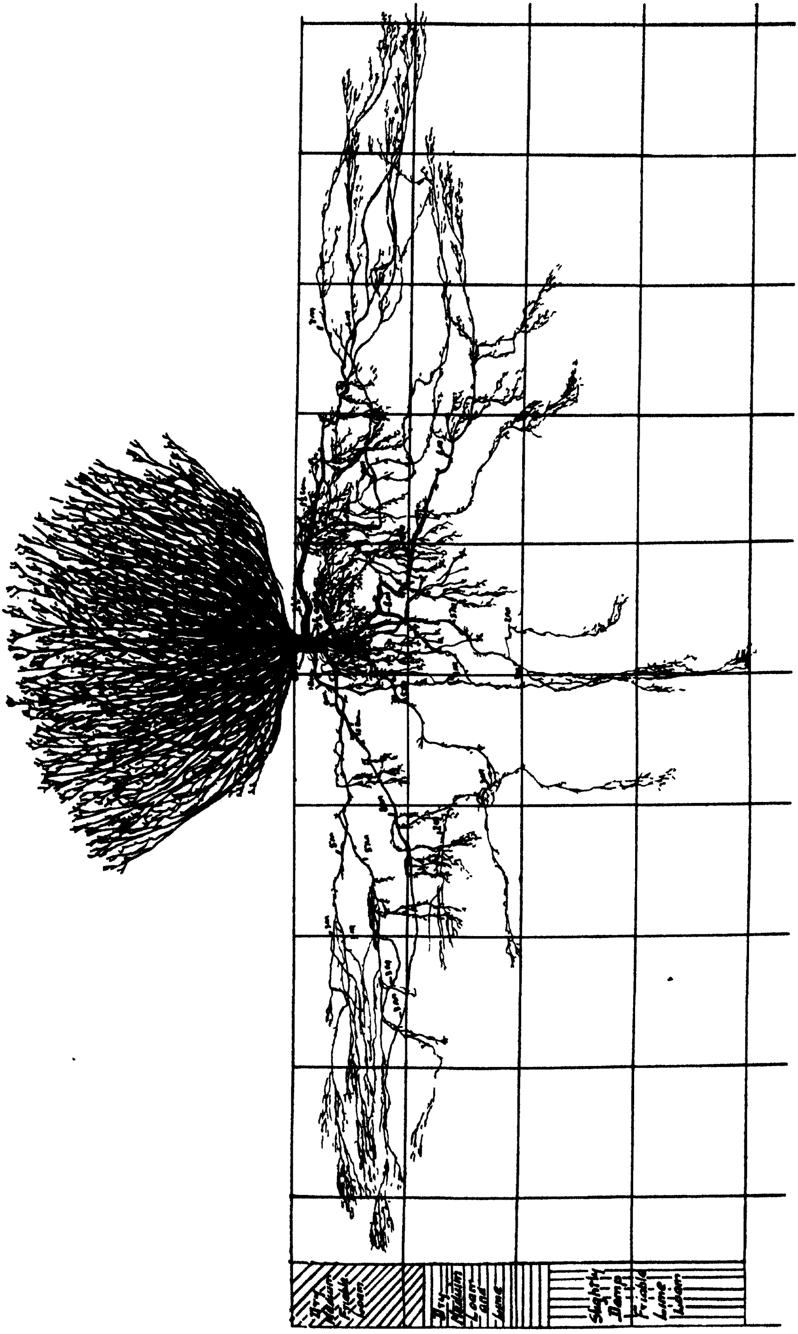


Ref. No. 3 B

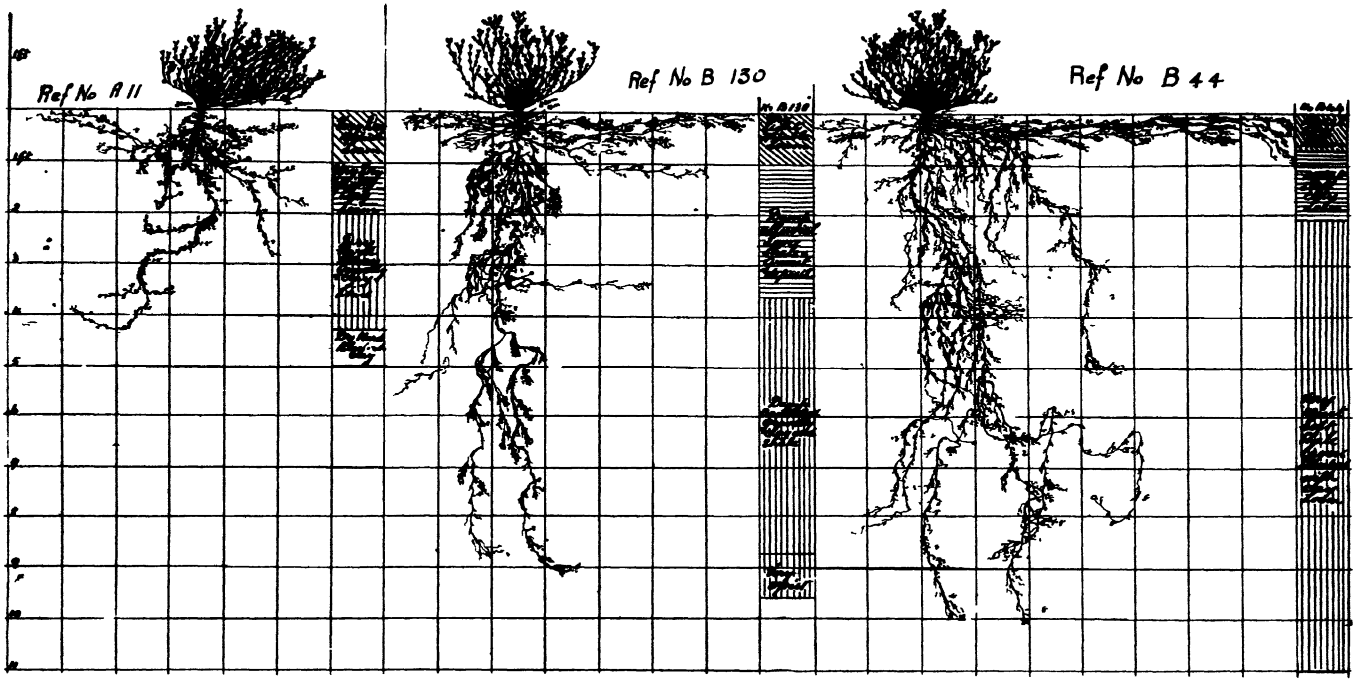
Root system bisect of mature "Groen Melkbos," *Euphorbia Burmanni* to entire depth of penetration. Plant growing in moist soil. Estimated age 4 years.



Root bisect of a mature shrub of *Euphorbia Mauretanica* to entire depth of penetration, showing the root parasite *Hydnora africana* by hatching.



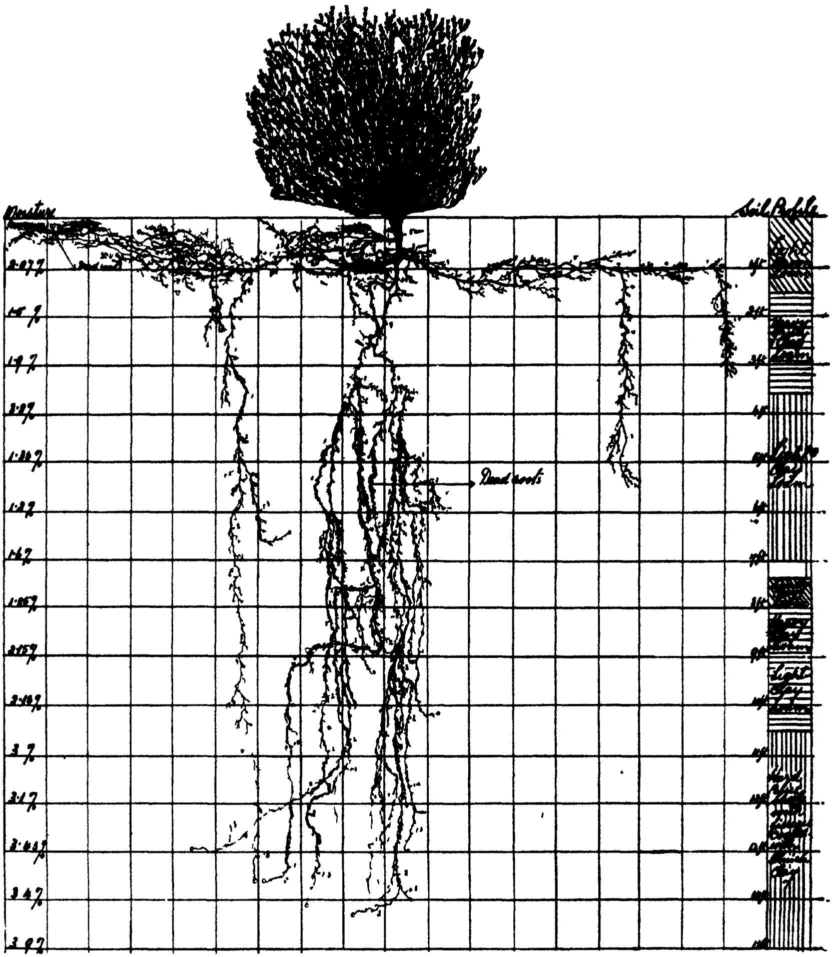
Ref. No. 3 F



Ref No. A 11.- Young *Ruschia multiflora* growing under natural arid conditions.

Re No. B 130. –Root system of a 14 months old *Ruschia multiflora* (Groot Bees Vygie), to entire depth of penetration Growing under natural arid conditions.

Re No. B 44. Root system of a 14 months old *Ruschia multiflora* (Groot Bees Vygie), to a depth of 10 feet when further excavation was discontinued. This plant was watered once weekly.



Ref. No. 6 A

Root system bisect of *Ruschia multiflora* (Groot Bees Vygie) to a depth of 14½ feet when further excavation was discontinued. The plant was growing under natural arid conditions.

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MONSONIA: THE DYSENTERY REMEDY

BY

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Read 7 July, 1939.

Abstract.

During the latter part of the nineteenth century the plant, Monsonia ovata, was used as a domestic remedy for the treatment of dysentery and typhoid fever; the results obtained with a brandy tincture prepared from the plant came to the notice of a Johannesburg practitioner, Dr. J. Maberley, who used the treatment in a series of cases and reported favourably thereon. He endeavoured to isolate the active constituent, and obtained two products: a water soluble tannin substance, " Tericin," and a water insoluble compound, "Entericin," which he regarded as the active principle. Maberley did not find " Entericin " superior to the whole plant preparations in clinical value.

Several Monsonia preparations were commercialised, but opinions of their value in the treatment of dysenteric conditions were divided.

The plant was investigated for its effects upon protozoa by Henry and Brown. These workers found it to be very toxic, which they attributed to the presence of phloroglucin tannin. They pointed out that " Entericin " is too ill-defined to be prepared, and apparently did not attempt to investigate it.

Marloth also examined the plant, and isolated a green, resinous substance as the active principle.

Recently Maberley has claimed to have obtained remarkable results with Monsonia preparations for the treatment of various conditions, ranging from typhoid fever to the common cold, and suggested that the wonderful healing properties of the plant were being overlooked in modern therapeutics. As the plant has not been previously investigated to any extent, it was regarded as desirable that this should be done with a view to isolating the active principle and ascertaining any medicinal value the plant may have.

The investigation of Monsonia burkei, a stock of which was available, was carried out by the usual phytochemical methods; an extract of the plant was prepared using 90 per cent. alcohol and examined chemically. It was found to contain 35 per cent. of pyrogallol tannin with other inert substances. The substance " Entericin " was also prepared according to Maberley's method and examined chemically; it consisted mainly of pyrogallol tannin.

Administration of the tincture prepared above, also of Entericin to animals by mouth produced no effects. When injected into frogs, the preparations produced " tanning " of the abdominal wall and death of the animal.

It was therefore concluded that any value the plant may have in treatment of dysenteric conditions depends entirely upon its tannin content. There is no justification for its use in other conditions, and it has no advantage over other tannin-containing preparations.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVI, pp. 238-245, December, 1939.*

A FURTHER CONTRIBUTION TO THE ECOLOGY OF THE HIGHVELD GRASSLAND AT FRANKENWALD, IN RELATION TO GRAZING

BY

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Read 7 July, 1939.

INTRODUCTION AND HISTORY.

The experiment described in the following pages, namely, the CC, DD, EE Series or the extension of the Isolation Transect, was laid out by Professor John Phillips and certain research students at Frankenwald in July, 1934. It consists of 12 plots each measuring 15 yards square. The site chosen was in typical " purple " or undisturbed veld (Glover, 1937). The soil is derived from the underlying old granite and is very gravelly with abundant quartz grains. Outcrops of laterite (Ouklip or iron sesquioxide) and quartz are abundant. The plots were all burned on the 13th July, 1934, in order to get the grasses as even as possible at the beginning of the grazing season. Grazing was commenced soon after the grasses started to shoot.

Treatments.

All 12 plots were grazed during the first season and at the end of each succeeding season, one plot in each series was protected from grazing, viz., CC 1, DD 1 and EE 1, were protected from grazing after the 1934/35 season, CC 2, DD 2 and EE 2 were protected from grazing after the 1935/36 season, etc.

CC 1, DD 1, EE 1, grazed during the 1934/5 season.
CC 2, DD 2, EE 2, grazed during the 1934/ to '36 seasons.
CC 3, DD 3, EE 3, grazed during the 1934/ to '37 seasons.
CC 4, DD 4, EE 4, grazed during the 1934/ to '38 seasons.

At the end of the 1937/38 season, therefore, all the No. 1 plots had one year's grazing followed by three years complete protection; the No. 2 plots, two year's grazing followed by two years of complete protection; the No. 3 plots, three year's grazing and one year's protection, and finally the No. 4 plots had four year's grazing. The control plots described in connection with another experiment (Glover and Van Rensburg, 1938), were also taken as control plots in this experiment.

Grazing Pressure.

The CC series were grazed in summer only, at a rate of about thirty cattle days (one cattle day = eight hours of grazing done by one animal) per plot per year.

The plots in the DD series were grazed moderately in summer only, at a rate of about 60 cattle days per plot per year.

In the EE series, the grazing pressure was about 120 cattle days per year. These plots were continuously overgrazed irrespective of the season.

Discussion of the Plots.

Methods of Attack.

As there were no quadrats listed in these plots at the outlay of the experiment, it was necessary to make a careful study of the phenological descriptions in order to detect certain changes brought about as the result of the various treatments applied. In 1939 however, three quadrats quarter metre square were listed in each of these plots. Although there are no previous figures for comparison, if CC 1, which had the lightest treatment, be taken as a basis or standard, these figures can easily be compared with those obtained in the other plots, and can in turn be compared with the control plots.

Plot CC 1.—" Lightly " grazed for one season followed by three years protection.

In this plot there definitely seems to be an advance in succession. Great similarity with the control plots is shown. This may be concluded from both the quadrat analysis and phenological observations. There is a large amount of dead material present. *Digitaria tricholaenoides* is only present in small quantities and appears to be dying out as a result of a decrease in light intensity caused by the taller bunch grasses. This was also noted in the plots described by (Glover and Van Rensburg, 1938). Furthermore, there is a consistent increase in *Trachypogon plumosus* and *Tristachya hispida*. *Urelytrum squarrosum* and *Tristachya Rehmannii* are both very conspicuous in the plot and although their abundance was noted when the experiment was first started, it seems likely that they have increased during the last few years. *Panicum natalense*, another grass apparently high in succession, is present in fair amounts. *Themeda triandra* and *Cymbopogon excavatus* are conspicuously absent. Apparently these as well as *Digitaria tricholaenoides* have diminshed or disappeared since the experiment was started. This is also in agreement with observations on *Themeda* in the control plots during 1938.

Plot CC 2.—" Lightly " grazed for two seasons followed by two years protection.

This plot resembles CC 1 to a very large extent. *Trachypogon plumosus* and *Tristachya hispida* are still dominant and there is a large amount of accumulated dead material. *Digitaria tricholaenoides*, however, is more abundant in this plot than in CC 1.

Plot CC 3.—" Lightly " grazed for three years and protected for one year.

This plot also corresponds to CC 1, in so far as *Trachypogon plumosus* and *Tristachya hispida* are most abundant. *Urelytrum squarrosum* and *Tristachya Rehmannii* are not nearly as frequent as in CC 1; *Elyonurus argenteus* and *Themeda triandra* are present in considerable quantities, and *Digitaria tricholaenoides* is more or less the same as in plot No. 2. The cover in this plot is very even. The figures obtained from the three quadrats listed in this plot are practically the same in each case for individual species as well as for the totals.

Plot CC 4.—" Lightly " grazed for four seasons.

Although grazing in this plot was not heavy enough to do much damage to *Trachypogon plumosus* and *Tristachya hispida*, there was a great increase in *Digitaria tricholaenoides;* the spreading of which definitely seems to be accelerated by treatment of this kind. *Heteropogon contortus* appears to be more abundant in this plot than in the previous ones, while *Urelytrum squarrosum* and *Tristachya Rehmannii* are almost completely absent. This certainly gives some indication of the resistance of the Highveld grassland. Where the grazing pressure is increased beyond a certain limit there follows a serious decrease in species such as *Trachypogon plumosus* and *Tristachya hispida.*

CC Series.—General.

It is interesting to note that in this series there is a gradual *decrease* in the percentages of *Trachypogon plumosus* and *Tristachya hispida* and a corresponding *increase* in the percentage of of *Digitaria tricholaenoides* from No. 1 to No. 4. Furthermore, *Eragrostis chalcantha*, *Elyonurus argenteus* and *Heteropogon contortus* tend to increase in the same direction as does *Digitaria tricholaenoides*, while *Brachiaria serrata* tends to decrease.

Plot DD 1.—" Moderately " grazed for one season followed by three years protection.

Plot DD 1 resembles CC 1 to a large extent, with *Trachypogon plumosus* and *Tristachya hispida* as the dominant species making up a very large percentage of the total cover. *Digitaria tricholaenoides* is present in small quantities, while the amount of *Brachiaria serrata* and *Eragrostis chalcantha* are considerable. *Urelytrum squarrosum* and *Tristachya Rehmannii* are frequent; *Cymbopogon excavatus* and *Themeda triandra* are practically absent. There is a very close resemblance between the quadrat figures of plot DD 1 and CC 1.

Plot DD 2.—" Moderately " grazed for two seasons followed by two years protection.

Although *Trachypogon plumosus* and *Tristachya hispida* still constitute a fairly high percentage of the total cover, *Digitaria tricholaenoides* is extremely abundant and brings the cover above

the normal percentage. *Elyonurus argenteus* and *Eragrostis chalcantha* are fairly frequent.

Plot DD 3.—" Moderately " grazed for three seasons and protected for one year.

In this plot there is a marked decrease in *Trachypogon plumosus* and *Tristachya hispida*, while *Digitaria tricholaenoides* is dominant, constituting about a third of the total cover. Apart from the decrease in *Trachypogon plumosus* and *Tristachya hispida*, there is no sign of deterioration. *Cymbopogon excavatus* and *Themeda triandra*, as well as *Brachiaria serrata*, *Elyonurus argenteus*, *Heteropogon contortus* and *Eragrostis chalcantha* are fairly frequent.

Plot DD 4.—" Moderately " grazed for four years.

A further decrease in *Trachypogon plumosus* and *Tristachya hispida*, and a further increase in *Digitaria tricholanoides* is noticed in DD 4. The latter species makes up between one-third and half of the total cover. There are signs of secondary species such as *Cynodon dactylon*, *Eragrostis* spp. and *Eleusine indica* beginning to come in, but in almost negligible amounts. *Themeda triandra*, *Elyonurus argenteus*, *Heteropogon contortus*, *Eragrostis chalcantha* and *Cymbopogon excavatus* are occasional to fairly frequent.

DD Series.—General.

In this series, the constant decrease in *Trachypogon plumosus* and *Tristachya hispida* from plot No. 1 to No. 4, and the constant increase in *Digitaria tricholaenoides*, *Eragrostis chalcantha*, *Heteropogon contortus* and *Themeda triandra* is even more marked than in the CC series. Besides a marked decrease in *Trachypogon plumosus* and *Tristachya hispida*, this stocking rate, which amount to about 60 to 70 cattle days per year, does not seem to have a detrimental effect on the veld. DD 4 compares unfavourably with CC 4, in which the stocking rate is half as great. If these treatments are maintained for a much longer period, it may prove to have detrimental effects, as a period of four years may not be long enough to indicate such changes.

Plot EE 1.—" Heavily " grazed for one year and protected for three years.

Also resembles CC 1 to a great extent, especially as far as the abundance of *Trachypogon plumosus* and *Tristachya hispida* is concerned, but *Digitaria tricholaenoides* is much more abundant than in either CC 1 or DD 1. *Tristachya Rehmannii*, *Eragrostis chalcantha*, *Brachiaria serrata*, *Elyonurus argenteus* and *Themeda triandra* are present in considerable amounts.

Plot EE 2.—" Heavily " grazed for two years followed by two years protection.

Shows signs of deterioration as a result of grazing treatment more clearly than any of the plots discussed so far. *Trachypogon plumosus* and *Tristachya hispida* are both still present in consider-

able quantities, but *Digitaria tricholaenoides* is very abundant, and a number of secondary species such as *Cynodon dactylon*, *Eragrostis* spp., *Hyparrhenia hirta*, etc., have already made their appearance. *Themeda triandra*, *Elyonurus argenteus*, and *Cymbopogon excavatus* are also present. The ground cover in this plot is much poorer than in EE 1.

Plot EE 3.—" Heavily " grazed for three years and protected for one year.

This plot has deteriorated badly as the result of grazing and large bare patches show conspicuously in several places. *Digitaria tricholaenoides* increased greatly while there is a marked decrease in the amount of *Trachypogon plumosus* and *Tristachya hispida*. *Elyonurus argenteus* and *Themeda triandra* are abundant; *Cymbopogon excavatus* fairly frequent, and *Hyparrhenia hirta* and *Aristida congesta* are present in small amounts. *Cynodon dactylon* has started to spread from several places in the plot.

Plot EE 4.—" Heavily " grazed for four years in succession.

Here deterioration is very marked due to the very severe grazing pressure. Even *Digitaria tricholaenoides* has been damaged to a large extent and gradually seems to be replaced by *Cynodon dactylon*. *Tristachya hispida* is still present in reasonable amounts, but *Trachypogon plumosus* has nearly disappeared altogether. *Tristachya Rehmannii*, *Urelytrum squarrosum*, *Andropogon amplectens* and *Panicum natalense* appear to be entirely absent. *Elyonurus argenteus*, *Eragrostis chalcantha* and *Eragrostis* spp. are occasional. Various annuals such as *Eleusine indica*, *Chloris virgata*, *Paspalum dilatatum*, *Digitaria horizontalis* and *Solanum capense* are present in considerable numbers.

EE Series.—General.

Again the decrease in *Trachypogon plumosus*, *Tristachya hispida*, *Elyonurus argenteus* and *Brachiaria serrata* from EE 1 to EE 4 is constant, while *Digitaria tricholaenoides* in this case is more abundant in plots 1, 2 and 3. No. 4 is the only plot where grazing has been detrimental to *Digitaria tricholaenoides*. Also in another experiment, overgrazing for five years proved to be detrimental to this grass (Glover and Van Rensburg, 1938). There is a general increase in *Eragrostis chalcantha* and a definite decrease in *Elyonurus argenteus* from EE I to EE 4. The appearance and increase of secondary species such as *Eragrostis* spp., *Cynodon dactylon*, *Hyparrhenia hirta*, *Cymbopogon excavatus*, *Eleusine indica*, etc., in the last three plots is of importance. Although there was no deterioration evident in the plot that was overgrazed for one year only, there definitely was deterioration in the plots overgrazed for more than one year.

Control Plots.

The same plots described by Glover and Van Rensburg in 1938 were taken as control plots for this experiment. Three

quadrats of quarter metre square were also laid out in these plots and as there was a very close resemblance between the results obtained from these and those obtained from the existing quadrats, the average figures of all the quadrats in the control plots were taken for comparison. The most striking here is the obvious increase in *Trachypogon plumosus* and *Tristachya hispida;* while *Digitaria tricholaenoides* and *Themeda triandra* apparently decreased.

Experiment in General.

In the same way as there are definite trends of development in each series from plots 1 to 4, so there also exists a gradation from the CC series to the EE series, and the difference between the plots becomes more marked as we approach those which have been grazed for the longest periods. The No. 1 plots with only one season's grazing followed by three years of protection are very similar, but in the No. 4 plots where grazing was continued over a period of four years, there is much greater difference between the individual plots.

It was considered preferable to list three small quadrats of quarter metre square instead of one large one in order to get a representative sample. In each case the average for each plot was taken for comparison. Throughout these plots, *Tristachya hispida* appears to be more abundant than *Trachypogon plumosus,* and it also seems to stand up longer or to more severe grazing than does *Trachypogon.* This is borne out in the quadrat results.

It is important to bear in mind that as these plots are very small, the number of cattle put in for grazing is relatively large and a considerable amount of droppings and urine accumulate in the plots. This naturally will have some effect on the vegetation.

CONCLUSIONS.

(1) *Trachypogon plumosus* and *Tristachya hispida* tend to increase in veld protected from grazing for any length of time. In the usual Highveld grassland at Frankenwald, *Tristachya hispida* appears to be more abundant than *Trachypogon* and it seems to endure trampling or heavy grazing for a longer period than *Trachypogon.*

(2) *Tristachya Rehmannii, Urelytrum squarrosum, Panicum natalense* and *Andropogon amplectens* also tend to increase in protected areas, and these species as well as *Trachypogon plumosus* and *Tristachya hispida* appear to belong to an advanced successional stage.

(3) The spreading of *Digitaria tricholaenoides* is encouraged by comparatively heavy grazing. When, however, the grazing pressure is too heavy, this grass is trampled out, and is replaced by *Cynodon* and other secondary species. When, on the other hand, *Digitaria tricholaenoides* veld is protected from grazing for any length of time, it is gradually smothered and dies out. This is also shown by quadrat results and conforms with results obtained in 1938 (Glover and Van Rensburg).

(4) In grazed plots, *Brachiaria serrata* and *Elyonurus argenteus* generally react in the same way as *Trachypogon plumosus* and *Tristachya hispida*, while *Eragrostis chalcantha* and *Heteropogon contortus* increase or decrease simultaneously with *Digitaria tricholaenoides*.

(5) *Themeda triandra* and *Cymbopogon excavatus* appear to be more abundant in the more heavily grazed plots where retardation of plant succession had occurred. Here also *Eragrostis* spp. and *Hyparrhenia hirta* occur.

(6) In plots that are "heavily" and continually grazed, deterioration begins to show in the second season, whereas after four years of "moderate" grazing there is hardly any sign of deterioration. *Cynodon dactylon* spreads rapidly after three or four years of ill-treatment, but the rate at which it spreads may depend upon the source and quantity in which it is present.

(7) None of the dicotyledons or monocotyledons such as *Gnidia capitata*, *Senecio coronatus*, *Senecio mollicomis*, *Sphenostylis angustifolia*, *Hyposis* sp. etc., seems to change as the results of the treatments.

(8) There appear to be two classes of grass which always tend to re-establish the equilibrium after some change has been brought about by any particular kind of grazing treatment. In the one class may be placed *Trachypogon plumosus*, *Tristachya hispida*, *Elyonurus argenteus* and *Brachiaria serrata*, and on the other, *Digitaria tricholaenoides*, *Eragrostis chalcantha*, *Heteropogon contortus* and *Themeda triandra*. The one class increases at the expense of the other, depending on the grazing treatment. The general trend of this may easily be followed out in the quadrat analyses.

ACKNOWLEDGMENTS.

I am indebted to Dr. John Phillips, Professor of Botany at the University of the Witwatersrand, Johannesburg, under whose guidance this work has been carried out, and who suggested that these results should be compiled.

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PERCENTAGE COVER IN PLOT CC 1, AND THE AVERAGE PERCENTAGE COVER IN THE CONTROL PLOTS, SERIES CC, DD, AND EE.

Plant species	Control	Plot CC 1	Series CC	Series DD	Series EE
Andropogon amplectens ...	·69	—	·03	·09	—
Aristida congesta	—	—	—	—	·05
Brachiaria serrata ...	·65	1·17	·80	·37	·41
Chloris virgata	—	—	—	—	·04
Cymbopogon excavatus ...	·01	—	—	·09	·08
Cynodon dactylon	—	—	—	—	·82
Digitaria horizontalis ..	—	—	—	—	·01
Digitaria monodactyla ...	·02	—	·09	·03	—
Digitaria tricholaenoides ...	1·13	1·00	2·77	5·31	3·88
Diplachne biflora	·39	·07	·02	—	·10
Eleusine indica	—	—	—	—	·10
Elyonurus argenteus ...	1·09	1·15	1·69	2·07	1·11
Eragrostis brizoides ...	·11	—	·10	·32	—
Eragrostis chalcantha ..	·37	·57	·66	1·31	·40
Eragrostis spp.	—	—	—	·02	1·43
Heteropogon contortus ...	·03	·44	·52	·64	·19
Michrochloa caffra	·07	·35	·33	·44	·16
Monocymbium ceresiiforme	·05	·11	·01	—	·01
Panicum natalense ...	·03	·40	·10	—	·03
Paspalum dilatatum ...	—	—	—	—	·02
Rhyncelytrum setifolium ...	—	—	—	—	·09
Schizachyrium semiberbe ...	—	—	—	—	·06
Sporobolus fimbriatus ...	—	·04	·04	·32	·02
Themeda triandra	—	·94	·29	·74	.67
Trachypogon plumosus ...	4·25	4 80	3·32	2·57	1·45
Tristachya hispida ...	6·70	4·71	4·59	3·63	2·55
Tristachya Rehmannii ...	·04	—	—	·07	·08
Urelytrum squarrosum ...	—	·13	·12	·04	—
Dicots	·23	·07	·06	·11	·15
Monocots	·02	—	—	—	·03
Sedges	·24	·36	·17	·10	·11
Total	16·12	15·07	20·29	18·23	14·32

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AN ACCOUNT OF THE MARINE ANGIOSPERMS OF INHACA, P.E.A.

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With 4 Text Figures.

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A preliminary account of the "sea-grasses" of Delagoa Bay was published two years ago by Mrs. M. Moss (1937). During July of 1937, the writer was able to visit the island of Inhaca and collect further material of these angiosperms, which she has since investigated in the laboratory, under the supervision of Mrs. M. Moss. The following is a brief account of this investigation:—

The island Inhaca, P.E.A., lat. 26°, long. 33°, is situated in the mouth of Delagoa Bay, 22 miles across the bay due east from the port Lourenco Marques. It is roughly oblong in shape, being 7 miles long from north to south and 4 miles wide from east to west. Probably due to the very gentle slope of the shores of Inhaca, the sea recedes for several hundreds of metres at spring ebb-tide. In so doing, it leaves exposed, or only shallowly covered, extensive flats of ripple-marked sand on which the marine angiosperms occur. These have been found in abundance on the undulated northern and southern coasts and on the straight, protected western coast, which looks out on to the bay; on the east coast, however, few marine angiosperms have been found.

Investigation into the systematics, supplemented by a study of the leaf anatomy of these marine angiosperms, has so far revealed that 7 species occur. The family Potamogetonaceae is represented by the following members:—

Cymodocea ciliata (Forsk.) Ehrenb. ex Aschers.

C. isoetifolia Aschers.

C. rotundata Aschers. and Schweinf.

C. serrulata Aschers. and Magnus.

Diplanthera uninervis (Forsk.) Aschers.; and the Hydrocharitaceae by the following:—

Halophila ovalis (R.Br.) Hook.

Thalassia sp.

In addition to *Halophila ovalis* (R.Br.) Hook., a fine variety of this species with elongate, narrowly oblong-lanceolate leaves has been found. So far, no intergrading forms between the species and this variety have been collected, but since C. H. Ostenfeld (1916) reports that the species as it occurs along the west coast of Australia varies very much with regard to the size and shape of the leaves, it has been decided to include the variety under *Halophila ovalis* (R.Br.) Hook. until further investigation has been made in the field.

With regard to the specimens of *Thalassia* sp. which have been collected, identification as to the exact specific name will not be possible until the male plants have been found. However, the structure of the female flower does not appear to agree with that of *Thalassia Hemprichii* (Ehrenb.) Aschers., the only species of the genus Thalassia which has so far been reported from the east coast of Africa.

Of the seven species listed above, three—*Halophila ovalis*, *Cymodocea ciliata* and *C. isoetifolia*—have previously been reported as occurring along the east coast of Africa south of the Tropic of Capricorn; three—*Diplanthera uninvervis*, *Cymodocea rotundata* and *C. serrulata*—have not until the present been reported south of the Tropic of Capricorn along the east coast of Africa; and finally, the seventh species—*Thalassia* sp.—may prove to be an entirely new report for the east coast of Africa.

An artificial key has been drawn up to serve in the identification of the marine angiosperms occurring along the coast of Inhaca and also along the east coast of Africa south of the Tropic of Capricorn. It is based on vegetative characters only, since flowering plants are difficult to obtain.

1. Leaves cylindrical ... ... *C. isoetifolia*
   Leaves dorsiventrally flattened 2
2. Leaves opposite ... ... *H. ovalis*
   Leaves alternate 3
3. Leaves up to 2 mm. wide with 3 veins *Diplanthera uninervis*
   Leaves more than 5 mm. wide with 9 or more veins 4
4. Sheaths continuing above the ligule to form 2 ear-like projections 5
   Sheaths terminating on a level with the ligule 6
5. Roots produced in pairs at each node; leaf scars open; leaf margin serrulate at apex. *Cymodocea serrulata*
   Roots produced singly at each node; leaf scars closed; leaf margin almost entire ... ... *C. rotundata*
6. Old leaf sheaths falling away; upright stems long, bare, ligneous; leaf margin deeply serrulate ... *C. ciliata*
   Old leaf sheaths persisting as torn, membranous remnants; upright stems short, covered with leaf sheaths, herbaceous; leaf margin almost entire *Thalassia* sp.

Fig. I.—Habit sketch of *Cymodocea ciliata* Female Plant (x½).

With regard to the sociology and the general distribution of these seven species along the shores of Inhaca, it has been stated in the preliminary account of the Inhaca sea grasses (M. Moss, 1937) that these occur in definite zones. A further study has been made along the western coast of the island, and this has revealed the presence of three zones.

The first or "narrow-leaved" zone, which stretches from about 50 metres from high-water tide mark to about 150 metres seaward, is sparsely covered with a very narrow-leaved form of *Diplanthera uninervis* intermingled with *Halophila ovalis.* The whole of the first zone is almost entirely exposed, at spring ebb-tide, for several hours during the course ot the tides. The sea grasses growing in this zone are inconspicuous, and only the upper 1-1½in. of the leaves lie exposed and flattened on the wet ripple-marked flats.

The second or "intermediate-leaved" zone stretches from about the 150 to the 250-metre mark seaward. Here there is an intermingling of the narrow-leaved *Diplanthera uninervis,* with the broad-leaved, acaulescent Cymodoceas, *C. rotundata* and *C. serrulata.* The zone is covered with water from 3-15 cm. deep at spring ebb-tide and the angiosperms form rich, dense meadows.

The third or "broad-leaved" zone extends from about the 250-metre mark seaward to where the water reaches a depth of one or more metres at spring ebb-tide. In this region, *C. ciliata* occurs in extensive communities, the long, supple, upright stems, with leaves clustered at their apices, being well adapted to withstand the wave action of the tide. The awl-shaped *Cymodocea isoetifolia* sometimes occurs intermingled with *C. ciliata* and sometimes forms pure colonies.

The uniformity of this zonation along the total west coast of Inhaca is not unexpected on a coastline which is straight or only gently curving, rockless, almost perfectly horizontal and looking out upon a large, sheltered, land-locked bay. Similarly, it is not unexpected that, on the eastern coast, which is rocky and exposed to the open sea, these angiosperms should be confined to sheltered rock pools and should be limited in number of individuals. On the northern and southern coasts, which are notable for the presence of deep tidal bays, extensive areas of "narrow-leaved," "intermediate-leaved" and "broad-leaved" zones are present. The exact boundaries between these zones have not as yet been investigated, but it has been found that where the tidal bays occur, the "narrow-leaved" zone greatly increases in width. Thus, on the southern coast, examination for a distance of 400 metres seaward from the innermost reaches of the bay has revealed a uniform zone of *Diplanthera uninervis* with *Halophila ovalis.*

Up to date, flowering material of only a few of these angiosperms has been collected. The male and female flowers and the fruits ot *Halophila ovalis* and of *Cymodocea ciliata* have,

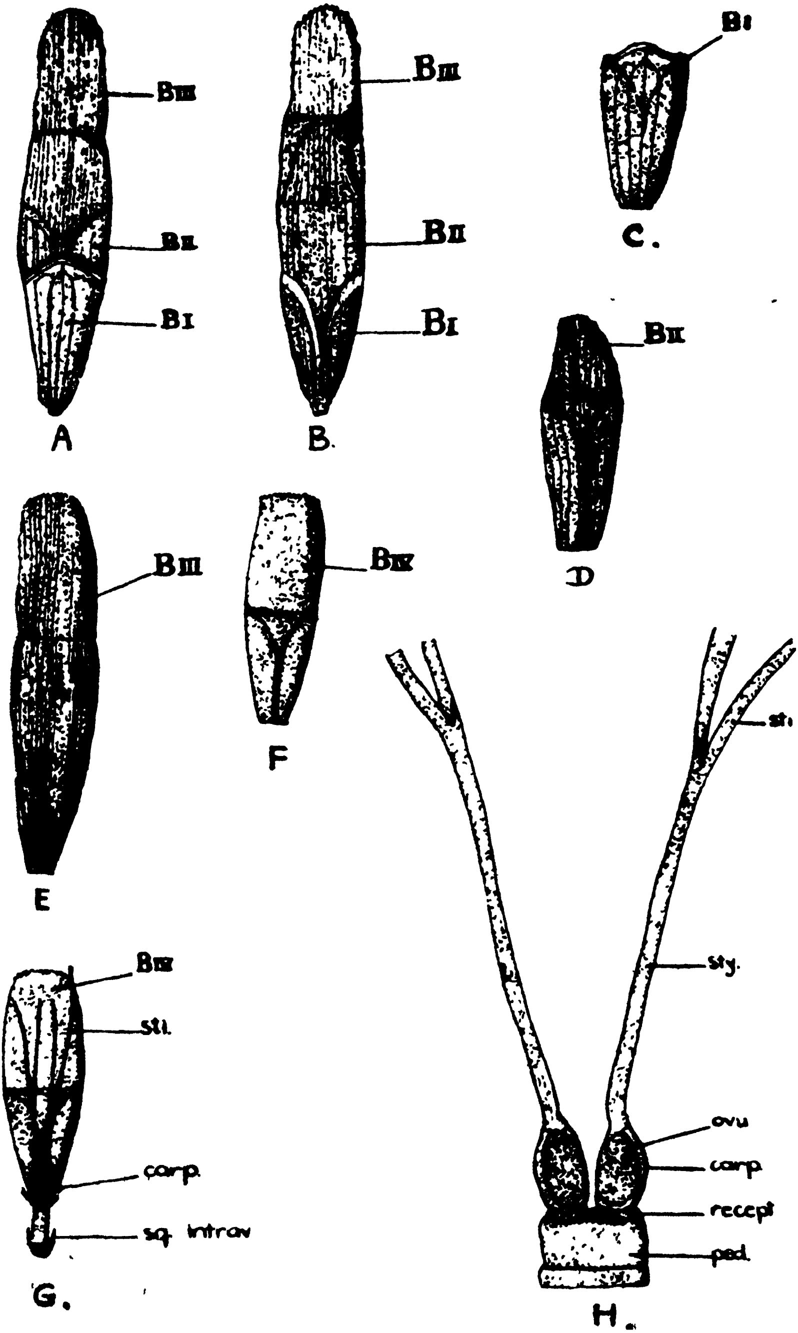

Fig. II.—Female Flower of *Cymodocea ciliata* (A–G × 1; H × 4).

however, been found. While the former species has been thoroughly investigated by I. B. Balfour (1879), the flowers in the latter are apparently rare and little known. The following is an account of the male and female flowers and the fruits of *C. ciliata.*

Cymodocea ciliata is dioecious, the male plant occurring in extensive communities along the shores of Inhaca, while the female plants have not as yet been found in such abundance. The flowers are solitary in the axils of the leaves, and only become exposed when, during the course of growth, the outermost of the apical cluster of leaves fall away (Fig. I.).

The *female flower* is pedicellate with a cushion-like, fleshy receptacle on which two bright green carpels, each with a comparatively short style and two long stigmas, are born (Fig. II H). These are protected by four leafy green bracts which are tinged with a pink pigment (Fig. II A, B). The shape and venation of these four bracts have proved to be constant in all the flowers examined and these characters are, therefore, reproduced in Fig. II C, D, E. F. Of the four bracts, three are membranous and clearly veined; the fourth (Fig. II F) is fleshy and obscurely veined. This fourth bract clasps the entire circumference of the pedicel and, at the same time, the female flower (Fig. II G). In a later stage, it functions as a float for the mature seeds (Fig. IV I).

The *male flower* is pedicellate and consists of two elongated stamens which are a yellowish-green colour tinged with red, and which are joined longitudinally by a pad of tissue (Fig. III G). These stamens are protected by four leaf-like green bracts tinged with pink, just as in the female flower (Fig. III A, B). In the male flower, too, the shape and venation of the four bracts have proved to be constant, and these characters are reproduced in Fig III C, D, E, F. It will be noticed that Bracts I (Fig. III C) and II (Fig. III D) in the male flower are exactly similar to those bracts in the female flower (Fig. II C, D); Bract III (Fig. III E) is, however, different from Bract III in the female flower (Fig. II E) in that it is always shorter than the preceding bract, has a blade which is distinctly narrower than the sheath, and shows two veinless lips which, in overlapping, enclose the male flower; further, Bract IV (Fig. III F) is very different from Bract IV in the female flower (Fig. II F), being much reduced (only 2 mm. long), elliptical in shape, membranous, and with only one median vein.

Details of the floral morphology coincide with those given in the generic description of Cymodocea by C. D. E. Koenig (1806) and need not therefore be discussed here.

A mature fruit consists of the fleshy Bract IV, the lips of which envelop the carpels and clasp them tightly, and two carpels, each of which bears a mature ovule (Fig. IV I). The bract lips ultimately fuse with the posterior portion of the sheath,

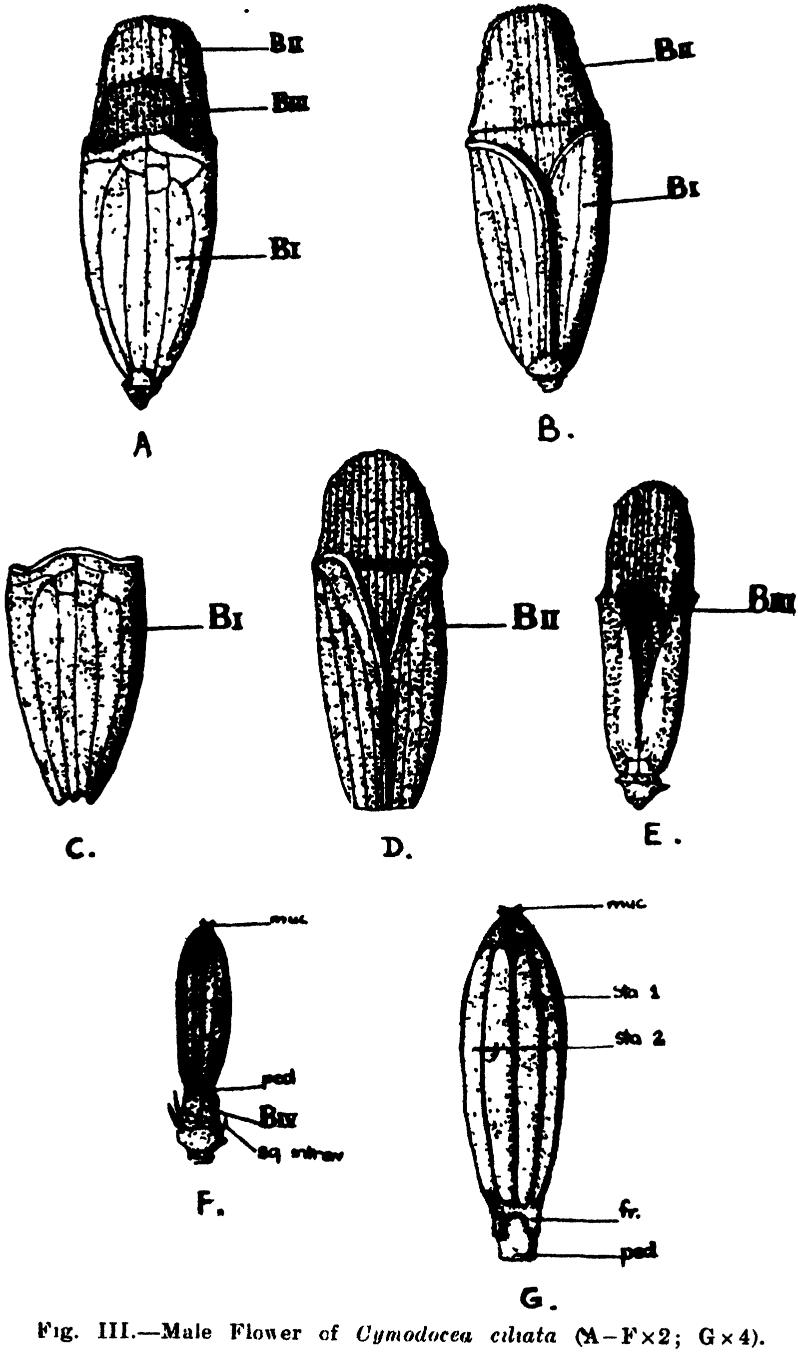

Fig. III.—Male Flower of *Cymodocea ciliata* (A–F×2; G×4).

and the entire bract functions as the float for the mature ovules. It is fleshy and so constructed that it will lie in only one position, i.e. so that the carpels are nearest the ground. However the fruit is placed, it naturally reorientates itself to this position.* As yet, no germinating seedlings have been found.

The development of the female flower has been worked out from the female material collected at Inhaca and examined in the laboratory. In a very young stage of the female flower, the two outermost bracts (I and II) are well developed, while Bract III is still short and cannot be seen, due to the enveloping Bract I (Fig. IV A). The stigmas at this stage are freely exposed. At a later stage, Bract III elongates and exceeds in length first Bract I and then, later, Bract II (Fig. IV B, C, D and E). This gradual increase in the length of the third bract is accompanied by the inclusion of the stigmas between Bract II and III. It seems probable, therefore, that fertilisation of the female flower takes place before the elongation of Bract III and while the stigmas are fully exposed. While Bract III is elongating, the fleshy Bract IV (which later functions as a float) begins to grow (Fig. IV E, F and G). It continues to elongate after Bract III has reached its full length. Thus growth continues until Bract III and IV are about the same length (Fig. IV H). At this stage, all the bracts, except the fleshy Bract IV, drop away (Fig. IV H and I).

The increase in the age of the flower is accompanied by the apical growth of the upright stem and the shedding of the outermost leaves of the apical leaf cluster. Thus, by the time the flower has developed into a mature fruit, it has been relegated from its apical position to a basal one on the frond (Fig. I). This mature fruit, which has become freely exposed to the elements—its own protective bracts having fallen away—eventually seems to become detached and to float some distance from the parent plant. On many upright shoots, the bare pedicels of flowers, each showing the closed scars of three bracts,

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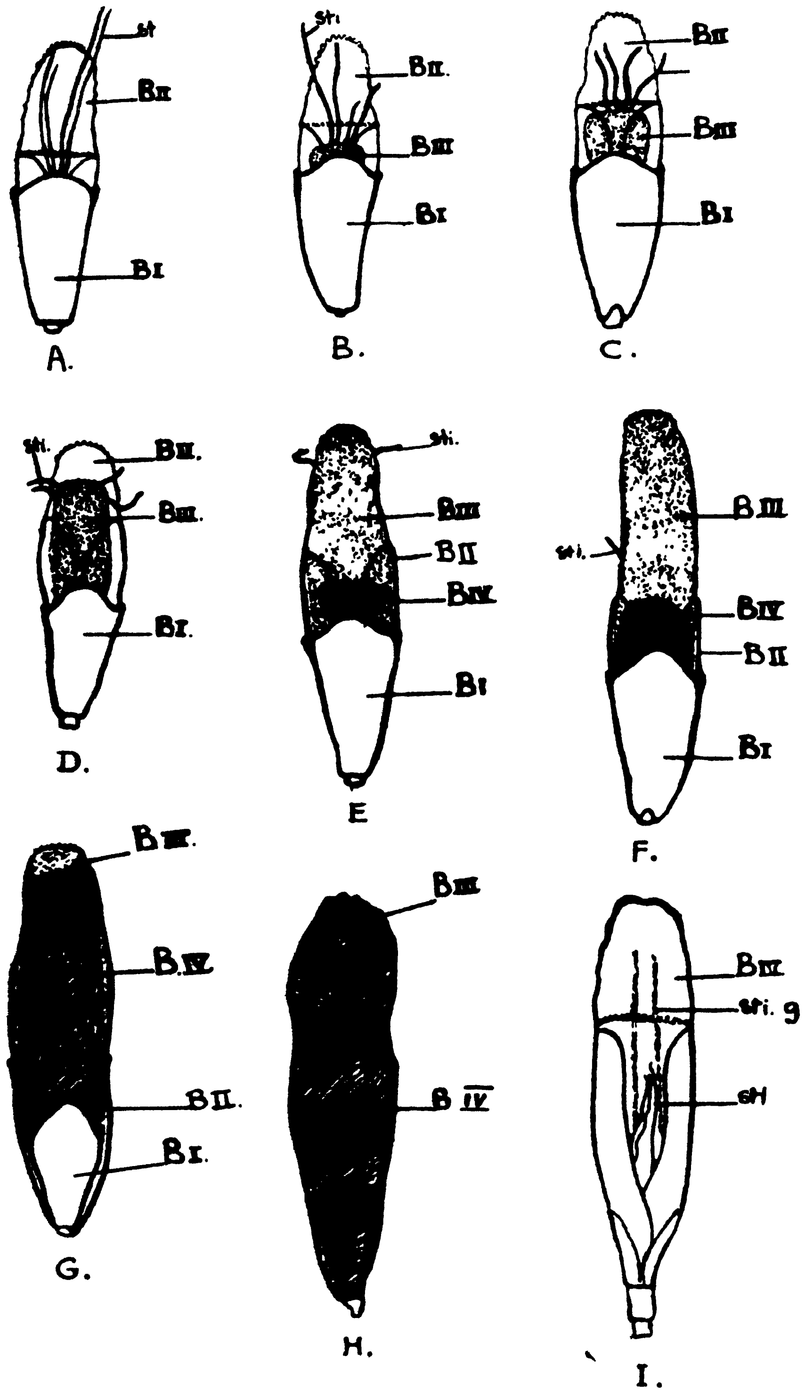
* While the present paper was in the Press, a letter written by Mr. J. E. Dandy, of the British Museum, to Mrs. M. Moss, which had previously been overlooked, was discovered. With regard to *Cymodocea ciliata*, Mr. Dandy writes: "Vegetatively, this species (i.e., *Cymodocea ciliata*) closely resembles *Amphibolis antarctica* (Labill.) Sond. & Aschers., and the two species were grouped together by Ascherson as a subgenus of Cymodocea. It has since been shown that *Amphibolis* is generically distinct from *Cymodocea* in having a curious 4-lobed fruit with viviparous development, the lobes of the fruit becoming pectinate and acting as holdfast organs. Until the fruit of *C. ciliata* is discovered, the generic position of this species must remain uncertain." Thus, the discovery of the mature fruit of *C. ciliata* along the shores of Inhaca has made it possible to state the exact generic position of this species. This fruit is neither 4-lobed nor viviparous (compare the description of the fruit of *C. ciliata* given above with the detailed account of the fruits of *Amphibolis antarctica* given by C. H. Ostenfeld (1916, pp. 28-30)), so that it becomes evident that *Cymodocea ciliata* is correctly placed in the genus *Cymodocea* and is generically distinct from *Amphibolis antarctica*.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have been found (Fig. 1). Disarticulation, therefore, seems to take place at the origin of Bract IV.

My thanks are due to Professor John Phillips, in whose department this work was carried out. I am further greatly indebted to Mrs. M. Moss for supervising this research throughout. In addition, I should like to thank Professor C. J. van der Horst for allowing me to accompany him on his zoological expeditions to Inhaca.

SUMMARY.

1. Marine angiosperms occur in abundance on the gently sloping western, northern and southern coasts of the island Inhaca, P.E.A., lat. 26°, long. 33°.

2. Investigation has revealed the presence of seven species —*Cymodocea ciliata*, *C. isoetifolia*, *C. rotundata*, *C. serrulata*, *Diplanthera uninervis*, *Halophila ovalis* and *Thalassia* sp.—three of which have not until the present been reported south of the Tropic of Capricorn along the African coasts. An artificial key to these species is provided.

3. The angiosperms occur in three zones—a "narrow-leaved," "intermediate-leaved" and a "broad-leaved" zone. The species found in each zone are enumerated.

4. An account of the female flowers, the male flowers, the fruits and the stages of development from young ovary to seed is given for the species *Cymodocea ciliata*.

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EXPLANATION OF FIGURES.

Fig. I.—Habit sketch of *Cymodocea ciliata* (Forsk.) Ehrenb, ax Aschers, female plant (×½). ff., female flower; fr., fruit; fr. st., fruit stalk persisting after fruits have broken away.

Fig. II.—Female flower of *Cymodocea ciliata* (natural sixe).

A. Adaxial view of flower.
B. Abaxial view of flower.
C. Bract I.
D. Bract II.
E. Bract III.
F. Bract IV.
G. Bract IV enveloping female flower.
H. Female flower on fleshy receptacle (×4).

B I, II, III, IV bracts enveloping the flower; carp., carpel; ped., pedicel; recept., fleshy receptacle; sti., stigma; sty., style; sq. intrav., squamulae intravaginales; ovu., solitary ovule attached laterally to the medial wall of the carpel.

Fig. III.—Male flower of *Cymodocea ciliata* (× 2).

A. Adaxial view of flower.
B. Abaxial view of flower.
C. Bract I.
D. Bract II.
E. Bract III enveloping male flower.
F. Male flower with Bract IV clasping the pedicel.
G. Male flower (× 4).

B I, II, III, IV bracts enveloping the flower; fr., membranous frill overlapping the pedicel; muc., 2-lipped mucron at apex of stamen; ped., pedicel; sq. intra., squamulae intravaginales; sta. 1 & 2, stamens joined by longitudinal pad of tissue.

Fig. 4.—Development of the fruit of *Cymodocea ciliata* (Diagrammatic).

A. Flower showing B I and II visible from adaxial side.
B. Flower showing B III visible from adaxial side.
C. }
D. } Further growth of B III visible from adaxial side.
E. B III as long as B II, thus enclosing stigmas. B IV visible from adaxial side.
F. }
G. } Further growth of B III and B IV.
H. B IV as long as B III, B I and B II shed.
I. B IV only remaining. Ovules enclosed in folds of fleshy B IV. Fruit mature.

B I, II, III, IV bracts enveloping the female flower; sti., stigma; sti. g., stigmatic groove.

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AN ECOLOGICAL STUDY OF LIGHT AND TEMPERATURE RELATIONS IN TYPICAL "PURPLE" VELD OF THE HIGHVELD: A CRITIQUE OF METHODS

BY

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Read 7 July, 1939.

The Sternpyranometer and the Eder Hecht Graukeil Photometer were studied from the point of view of their efficiency and use to the field ecologist. This investigation was carried out at the University Botanical Research Station at Frankenwald.

A COMPARISON BETWEEN THE RADIATION VALUES OBTAINED BY THE STERNPYRANOMETER AND THE LIGHT VALUES OBTAINED BY THE EDER HECHT PHOTOMETER.

The Sternpyranometer.—This instrument was invented by Professor Linke, Frankfurt-Main, in 1935. Two of these instruments were connected to a recording galvanometer made by Hartmann and Braun. The Sternpyranometer operates on the thermo-electric principle. There are black and white parts arranged alternatively on the surface. Under the white parts, there are one set of junctions, and another set under the black parts. By the subtraction of the radiation and air heat absorbed by the white parts from that absorbed by the black, an indication of radiation is recorded, which is calibrated so that the results can be represented in gm. cals. per sq. cm.

Considering this instrument from the field ecologist's point of view, it has several marked advantages over other instruments that measure radiation. A continuous record of radiation intensity is obtained. The records from any one instrument can be standardised by an instrument such as a Panzer-Aktinometer.

The Sternpyranometer has several disadvantages. It records total radiation, whereas a measurement of visible light is often much more useful in ecological researches. The instruments are expensive, as a standard instrument must be purchased together with the Sternpyranometers. If a Panzer-Aktinometer is bought, the total cost of the instruments is in the region of £220. The instruments require considerable attention to be kept in good working order, and the evaluation of the records requires time.

The Eder Hecht Photometer.—This instrument makes use of a photochemical method of measuring light. It is sensitive

to the shorter wave-lengths of light. A wedge of opalescent diffusing glass is set in a metal frame, behind this is a strip of glass, bearing a blackened celluloid scale. The deneness of the blackening increases in logarithmic order, and the scale is marked out in divisions 0 to 152. A strip of silver chloride paper is placed behind the scale. This paper has a maximum sensitivity at about λ450, a low sensitivity at λ520 and is not affected by wave-lengths longer than λ570.

There are three types of photometers supplied by the Dorno Physikalisch Meteoroligisches Observatorium, Davos, Switzerland. They have the following wedge constants:—

0·305. This model is used if daily integrations of light are required.

0·188. In South Africa, this model can be exposed for approximately 15 minutes in strong direct light.

0·401. This is the long period photometer, and can be exposed for seven days in Switzerland.

The relationship between scale divisions and Relative Light Intensity Sums is a logarithmic one, so that at the higher scale divisions, the Relative Light Intensity Sums increase rapidly The errors in evaluating the readings are considerable as an error of ± 2 scale divisions in the scale reading may introduce an error of ± 15 per cent. in the Relative Light Intensity Sums. Hecht and Morikofer (1939) have considered the question of the reading of the strips. They come to the conclusion that each research worker should use the method that he considers to give the most reliable results. For general purposes, they recommend the method of O. Krumpel, which they describe in detail.

These authors found that the Agfa Neutral Toning and fixing bath resulted in a drop in the scale divisions. In a group of 45 strips they found that the photometer of wedge constant 0·305 dropped 24 scale divisions, while the 0·188 dropped 26 scale divisions. In previous experimental work carried out in 1935 and 1936, the author working with some 300 strips, found that the mean drop in the scale divisions was 12 in the photometer with the wedge constant 0·305, while the mean drop in the photometer with the wedge constant 0·188, was 23 scale divisions.

The Eder Hecht photometer has definite disadvantages in the errors that are incurred in the reading of the strips, and in the fact that there is only one light intensity value given for the period of exposure. On the other hand, the instrument is an inexpensive one, costing about £7. To eliminate errors as far as possible, two photometers should be exposed simultaneously. If the Relative Light Intensity values are considered over monthly or yearly periods, there is evidence to show that the photometer is sufficiently accurate for field measurements

of light conditions. In any readings taken with the photometer, the worker should have a clear idea of the possible ratio of red to blue light in the spectrum on that day.

Further details with regard to the construction and operation of the Eder Hecht Photometer are given in previous publications.

Comparison.—As the Eder Hecht Photometer is sensitive to the shorter wave-lengths only, while the Sternpyranometer is measuring total radiation, it is necessary to consider the possible changes in the ratio of the short wave-lengths to total radiation. Water vapour absorbs strongly in the infra-red region, while blue light is more readily scattered than red light. When the diameter of the particles is larger than the wave-lengths of the incident light, diffuse reflexion occurs which is equally effective for all wave-lengths. Considering the rapid changes in the dust and water content of the atmosphere, the ratio of the short wave-lengths to total radiation is an extremely complex and variable one.

An Eder Hecht Photometer and a Sternpyranometer were set up in the field on a site with a good clear horizon. Daily total Relative Light Intensity values from the Photometer were correlated with gram calories per sq. cm. per day from the Sternpyranometer. These readings were taken from December, 1937, to October, 1938. The correlation coefficient "r"— + ·70 $\pm$ ·04 is significant. Taking the Sternpyranometer as a standard, it would appear that, over a period of time, the Photometer will give a fairly accurate impression of the light intensity. Mean monthly values from December, 1937, to October, 1938, showed that there was a general agreement between the readings from the two instruments in all months except May and June. Again taking the Sternpyranometer as a standard, if daily or monthly records are required from the Photometer, at least two Photometers must be exposed simultaneously.

The general conclusions were reached that the Sternpyranometer is an accurate field instrument for the measurement of radiation, but the cost of the instrument is too high, and the time necessary to keep the instrument in good working order too great, for this instrument to be extensively used in the field. The Eder Hecht Photometer is a reliable field instrument if a large number of records are considered, or if several photometers are exposed simultaneously. The long period photometer with the wedge constant 0·401 is recommended for the measurement of high light intensities.

A Brief Survey of Radiation and Light Relations in Typical "Purple" Veld of the Highveld.

In the choice of an instrument to measure light relations in plants, the particular aspect of the problem of plant

behaviour to be studied should be kept in mind. According to Popp and Brown (1934), the behaviour of different species is so varied that for a general study of the plant, it would make little difference to which region of the visible spectrum the instrument was most sensitive. Of the little work that has been carried out on the effects of the infra-red region on plants, Arthur (1934) reports that the infra-red region has not a marked influence on the main plant processes, except transpiration, where it supplies the energy required for the evaporation of the water.

For this study in typical "purple" veld, both the Sternpyranometer and the Eder Hecht Photometer were used. A pyranometer and a photometer were exposed on top of a pillar to measure total radiation. A second pyranometer and a second photometer were situated in the grass. The latter instruments both measured radiation about 3 inches above the ground level. The plants which grew most abundantly near the instruments were:—*Alloteropsis semialata* Hitchcock; *Trachypogon plumosus* Nees; *Urelytrum squarrosum* Hack; *Tristachya hispida* (Thunb.) Schum. (Jukgras); *Andropogon amplectens* Nees; *Hypoxis rigidula* Baker; *Veronia Kraussii* Sch. Bip.; *Vernonia monoccphala* Harv.

Radiations Relations Recorded with the Sternpyranometer.—During the summer months, part of the direct solar beam fell on the Sternpyranometer in the grass, while during the winter months the instrument was completely in the shade. The rise and fall of the sun and shade curves during the summer months was similar; this was not found to be so during the winter.

Considering the strength of the relationship between the sun and shade values, the following correlation coefficients were found.

Time	Correlation Coefficient	Error
December, 1937 to October, 1938	+ ·61	± ·04
June and July, 1938	– ·50	± ·11

The negative relationship shown during the two months is the result of marked increases in the shade intensities on days with scattered clouds, due to the reflected and scattered light from the clouds.

Considering the percentage ratio of shade to sun, it was found that a reduction of the radiation intensity by the grass was, on some days, as much as 97 per cent. Similar reductions of light intensity were measured by the Weston Photronic Cell in 1936.

Various authors have found that the main spectral changes in radiation under vegetation are in the blue region. As this is

so, and it is this region that is effective in producing a plant of normal stature, it would appear that the Sternpyranometer is not suited for the measurement of light relations in vegetation.

Light Relations Recorded with the Eder Hecht Photometer. —Throughout the whole year the direct solar beam fell on a portion of the Eder Hecht Photometer in the grass. There is a general agreement in the trend of the sun and the shade curves. This indicates that the difference between the Eder Hecht photometer and the Sternpyranometer values, is not due to errors made in the reading of the strips, but must be due to either the differences in the spectral quality of the light, or to the variations in the photochemical reactions ot the silver chloride paper in the Eder Hecht photometer.

To estimate the correlation between the sun and shade values, the coefficient $r = +\cdot 63 \pm \cdot 05$ was found. A similar coefficient was found with the readings from the Strenpyranometer.

During the winter, there is a tendency for the light intensity to be more reduced by the grass cover on cloudless days than on days of scattered clouds.

The photometer is sensitive to the blue region of the spectrum, which is a region important in the study of plant relations, but only one reading of light intensity is obtained for the daily variations in light intensity. The instrument cannot be checked so that the errors incurred cannot be eliminated.

A Study of the Soil Temperature Factor in Typical "Purple" Veld.

Here the relationship between soil temperature and radiation is considered. Light intensity and quality has an effect not only on the aerial and edaphic factors, but it is vitally important in conditioning the plant responces to these factors. No study of these factors is complete without a simultaneous study of light conditions.

The Sternpyranometer was used to record the radiation, and soil thermometers, manufactured by Hartmann and Braun, were used to record surface and 8in. depth temperatures under typical "purple" veld. The thermometers were platinum resistance ones in lead tubes, connected to a double coil galvanometer which recorded temperatures every minute.

One soil thermometer was placed on the surface of the ground under a dense clump of grass. The other was placed horizontally at a depth of 8in. below the surface of the soil. The air temperature was measured in a Stevenson's screen.

All results were found to be mathematically significant.

The Effect of Radiation upon Air and Soil Temperatures.— A general agreement was found between radiation intensity and the mean monthly air and soil temperatures, but there was no

agreement between the mean temperature amplitude and the radiation intensity. Air and surface maximum temperatures were found to be more influenced by radiation than was the maximum temperature registered at 8in. depth. On the other hand, the amplitude of the 8in. depth temperature was more affected by radiation than either the air or grass temperature amplitudes.

The grass temperature on cloudless days tended to follow the direction of the radiation curve, but its magnitude was modified by air temperature values. On cloudless days the maximum air and grass temperatures were found to be the same. In the evening after a cloudless day, the air temperature was higher than the grass temperature. For the whole year, the mean difference between the air and grass temperatures after a cloudless day was 1·4°C. On cloudy days, the general trend of the air and grass temperatures was similar to that of the radiation intensity.

The radiation intensity shows no marked relationship with the magnitude of the air and surface temperatures. There was no marked difference between the maximum air and surface temperatures on cloudy days. The minimum air temperature values after cloudy days were the same or lower than the grass temperature minima.

The conclusion was drawn that, while radiation has a marked effect upon soil temperatures, this effect is modified by local conditions of wind, soil moisture and plant transpiration.

The Relationship between Air, Surface and Depth Temperatures.—A combination of factors influence the air and soil temperatures. Air temperature is to a large extent influenced by soil temperatures. So, indirectly, the factors which influence soil temperatures affect air temperatures. The most important of these is plant cover, which not only reduces the radiant heat to as much as 4 per cent. of the total incident radiant heat, but it decreases the air heat by absorption.

Mean annual air and grass temperatures were found to be the same, while the 8in. depth was higher than the mean grass temperature. The mean difference was 0·8°C.

The highest maximum air and grass temperatures were approximately the same, while the 8in. depth temperature was lower. The mean difference between grass and 8in. highest maximum temperatures was 7·9°C. The lowest air temperatures were 1·2°C. below the lowest grass temperatures. The lowest 8in. temperatures were 5·5°C. above the lowest grass temperatures. No significant difference was found between mean maximum and minimum air and grass temperatures. The 8in. mean maximum temperature was 5·7°C. below the mean maximum grass temperature, while the mean minimum 8in. value was 4·1°C. above the mean grass temperature.

The average time for the occurrence of air and grass maxima is 14^{00} to 15^{00}. This is two hours after the average radiation maxima occur. The 8in. depth temperature maxima occur 5 hours after the grass temperature maxima occur. The minimum air and grass values occur in the hour before sunrise, while the 8in. depth minima occur 5 hours later.

The grass temperature has a slightly greater range of values than the air temperature. The mean difference was 0·7°C. The 8in. temperature had a smaller amplitude than the grass temperature. The mean difference in this case was 10·4°C.

The conclusion was reached that there was a close agreement between the air and soil temperatures. The mean depth temperature values were similar to the mean air and grass temperature values, but the range of the depth temperatures was much smaller.

General Conclusions.

The Sternpyranometer is an accurate instrument for the measurement of radiation in the field. It is expensive and is influenced mainly by the long wave-lengths, a region not so important in plant studies as the short wave-length region.

The Eder Hecht Photometer is not a very accurate instrument for the measurement of light. Its low cost and easy manipulation in the field, together with its sensitivity in the short wave-length region of the spectrum, makes it a very useful instrument for field ecological work.

The most marked results from a study of radiation and light relations in typical " purple " veld, was the increase in the shade intensities on days of scattered cloud due to the reflected rays from the clouds. This was so marked that a negative correlation was found between sun and shade values.

In a study of radiation and temperature relations. it was found that radiation had a marked effect upon soil temperatures. Air temperatures and grass temperatures under typical " purple " veld were found to be very similar. The soil temperature 8in. below the surface showed a marked lag.

Summary.

1. The Eder Hecht Graukeil Photometer and the Sternpyranometer nach Linke are considered from the point of view of their efficiency in field ecological work.

2. A study of radiation and light relations in typical " purple " veld made with Sternpyranometers and Eder Hecht Photometers is considered.

3. Radiation and air and soil temperatures in typical " purple " veld are considered from the point of view of their inter-relationships.

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FURTHER INVESTIGATION ON THE OSMOTIC VALUES OF THE LEAF SAPS OF CERTAIN SOUTH AFRICAN HIGHVELD GRASSES

BY

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With 1 Text Figure.

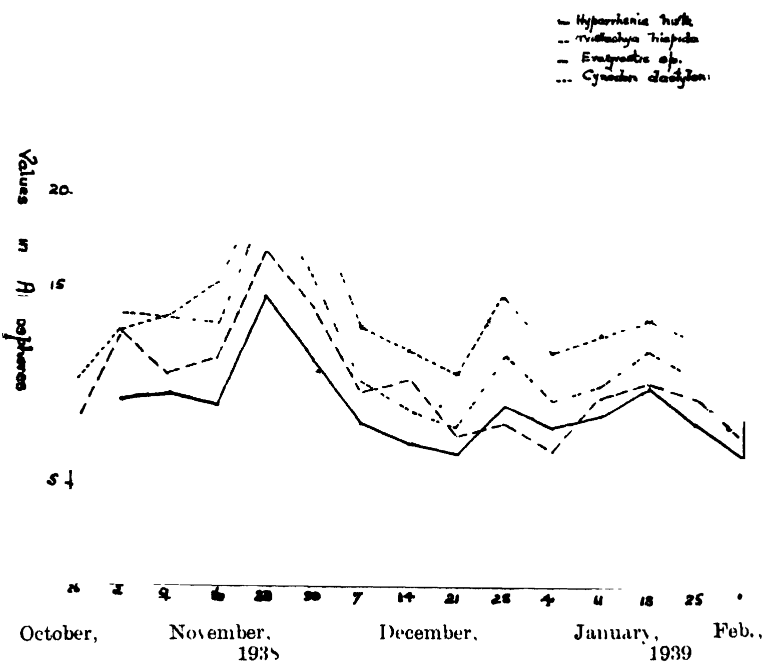
Read 7th July, 1939.

The study of the osmotic values of certain South African Highveld grasses, initiated in March, 1937, has been continued with other species of grasses from the Botanical Research Station at Frankenwald, from 26th October, 1938 to 1st February, 1939. The selected species were *Hyparrhenia hirta* (Linn.) Stapf, *Tristachya hispida K.* Schum., *Eragrostis* sp. and *Cynodon dactylon* Pers. The same method was adopted as described previously (South African Journal of Science, Vol. XXXV, pp. 317-318, 1938), great care being exercised that the grass leaves in each species were as uniform as possible. The leaves were gathered weekly on the same day, frozen overnight on solid carbon dioxide and the sap expressed at a pressure of 20 tons to the square inch. The osmotic pressures were then determined in atmospheres from the freezing point depressions. Soil samples at a depth of 6 inches were collected, the moisture content found and expressed as percentages of the dry weight. The amount of water present in the leaf saps was also determined for the selected grasses by oven drying at a constant temperature of 96°C. The moisture present was calculated at a percentage of the total amount of sap.

From the graph showing the osmotic values of the four species of grass for the period of investigation, the striking similarity in the curves was again noted, with the exception of *Tristachya hispida* which showed slight deviation from the normal trend.

The *highest osmotic value* for this period was observed in *Cynodon dactylon*, reaching a value of 21·03 atmospheres on the 23rd November, 1938. The lowest recorded value of 6·77 atmospheres, for the same period, occurred in *Hyparrhenia hirta*,

on the 21st December, 1938. The lowest value recorded for *Tristachya hispida* was only slightly higher, being 6·92 atmospheres on the 4th January, 1939. *Eragrostis* sp., except on the 2nd November, 1938, showed a lower osmotic value than *Cynodon dactylon*, but, in general, a higher osmotic value than *Tristachya hispida*. The *average osmotic values* for the time of investigation were 9·20 atmospheres in *Hyparrhenia hirta*, 10·60 atmospheres in *Tristachya hispida*, 12·02 atmospheres in *Eragrostis* sp. and 13·68 atmospheres in *Cynodon dactylon*.



Graph showing the Osmotic Values of *Hyparrhenia hirta*, *Tristachya hispida*, *Eragrostis* sp. and *Cynodon dactylon*.

The ranges of osmotic pressure were 8·16 atmospheres, 7·27 atmospheres, 11·68 atmospheres and 10·96 atmospheres in *Hyparrhenia hirta*, *Tristachya hispida* *Eragrostis* sp. and *Cynodon dactylon* respectively. It will thus be seen that for this period, the highest range was noted in *Eragrostis* sp., and the lowest in *Tristachya hispida*. The four species examined reached their peak on the same date, that is, on 23rd November, 1938, but the lowest values did not occur simultaneously. The minimum values for *Hyparrhenia hirta* and *Eragrostis* sp. were recorded on 21st December, for *Tristachya hispida* on 4th

January, with low values both on the 21st November, 1938, and 1st February, 1939, and for *Cynodon dactylon* on the 26th October, 1939. Low values approximating to its minimum value were recorded in *Cynodon dactylon* on 21st December, 1938, and 1st February, 1939.

It was again noted that there was no direct relationship between soil moisture content at a depth of six inches and the osmotic values. This may, in part, be accounted for by the heterogenous nature of the soil in this region. For all the species, with the exception of *Tristachya hispida*, the maximum osmotic value coincided with the minimum soil moisture content, while in *Tristachya hispida*, the difference between the soil moisture content on this date and the minimum recorded value was very slight.

The lowest osmotic value coincided with the maximum soil moisture content only in the case of *Eragrostis* sp., though the osmotic values for the other three species of grass at the highest soil moisture content approximated to their lowest values.

With regard to the percentage of sap expressed, there was no direct relationship with the osmotic values.

The highest percentage of sap expressed for the period was recorded in *Tristachya hispida* with a value of 37·21 per cent., and the lowest in *Eragrostis* sp. with a value of 10·56 per cent.

The average percentages of sap were 26·67 for *Hyparrhenia hirta*, 26·93 for *Tristachya hispida*, 17·39 for *Eragrostis* sp., and 15·53 for *Cynodon dactylon*.

The percentage of moisture in the sap was very similar in the four species of grass examined, but also showed no absolute relationship with the osmotic values. The maximum percentage of 98·05 was noted in *Hyparrhenia hirta*, and the minimum of 89·99 in *Tristachya hispida*. The average percentages were 94·60 for *Hyparrhenia hirta*, 93·27 in *Tristachya hispida*, 93·69 in *Eragrostis* sp. and 92·38 in *Cynodon dactylon*.

No seasonal trend could be noted for so short a period of observation.

If the osmotic values may be regarded as affording some indication as to their hardiness with regard to drought and frost resistance, of the four species examined, *Cynodon dactylon* may be considered the hardiest.

The osmotic values also appear to give some indication of the successional stages in the grasses observed, higher values occurring in those of a lower stage and vice versa, but further research with many more species over a number of years is necessary before the relation between osmotic values and plant succession may be established.

TABLE I—*Hyparrhenia hirta.*

Date of Collection.	Osmotic Value.	Percentage of Sap.	Percentage of Soil Moisture.	Percentage of Water in Sap.
26-10-38 ...		No collection		
2-11-38 ...	9·53 atm.	20·46 ...	6·52 ...	94·39
9-11-38 ..	9·69 ..	20·00 ...	6·36 ...	94·37
16-11-38 .	9·09 ...	36·08 ...	5·71 ...	94·81
23-11-38 ...	14·93 ...	29·14 ...	3·22 ...	91·88
30-11-38 ..	11·57 ..	16·98 ...	3·24 ...	92·09
7-12-38 ...	8·33 ...	26·87 ...	9·92 ...	93·91
14-12-38 ...	7·44 ..	31·36 ...	10·24 ...	94·44
21-12-38 .	6·77 ..	35·41 ...	11·82 ...	95·73
28-12-38 .	9·17 ..	32·91 ...	8·07 ...	94·46
4- 1-39 ..	8·07 ..	25·70 ..	12·02 ...	93·59
11- 1-39 ...	8·69 ..	25·17 ...	8·26 ..	96·48
18- 1-39 .	10·29 ..	25·15 ..	5·55 ...	98·05
25- 1-39 .	8·38 .	27·34 ..	11·81 ...	94·75
1- 2-39 ..	6·93 ..	18·75 ...	8·84 ...	95·46

TABLE II—*Tristachya hispida.*

Date of Collection.	Osmotic Value.	Percentage of Sap.	Percentage of Soil Moisture.	Percentage of Water in Sap.
26-10-38 ..	7·88 atm.	34·90 .	9·31 ..	92·98
2-11-38	12·79 ...	28·12 ...	8·56 ..	92·99
9-11-38 .	10·85 ...	29·65 ..	5·44 ...	93·59
16-11-38 ..	11·51 ...	36·05 ...	3·26 ...	93·98
23-11-38 ..	10·79 ..	12·20 ..	2·44 ...	89·99
30-11-38 ...	14·19 ...	23·11 ...	2·28 ...	91·27
7-12-38 ..	9·95 ...	22·22 ...	7·06 ...	92·74
14-12-38 ...	10·54 ...	35·05 ..	10·63 ...	95·23
21-12-38 ..	7·73 ...	37·21 ...	8·84 ...	94·30
28-12-38 ..	8·33 ...	27·96 ...	8·54 ..	94·68
4- 1-39 ...	6·92 ...	24·15 ...	10·81 ..	94·86
11- 1-39 ...	9·63 ..	18·52 ...	10·18 ...	93·52
18- 1-39 ...	10·37 ..	18·77 ...	5·27 ...	90·37
25- 1-39 ...	9·71 ...	27·81 ...	13·25 ..	94·20
1- 2-39 ...	7·54 ...	28·17 ...	6·67 ...	94·10

TABLE III—*Eragrostis* sp.

Date of Collection.	Osmotic Value.	Percentage of Sap.	Percentage of Soil Moisture.	Percentage of Water in Sap.
26-10-38	No collection			
2-11-38	13·83	10·56	4·01	92·01
9-11-38	13·55	12·15	4·58	92·29
16-11-38	13·45	13·33	4·12	92·72
23-11-38	19·70	10·54	2·40	91·86
30-11-38	15·73	26·09	3·33	94·33
7-12-38	10·48	22·77	7·05	95·55
14-12-38	8·97	25·43	10·61	95·32
21-12-38	8·02	20·39	10·14	95·84
28-12-38	11·91	20·14	6·75	94·67
4- 1-39	9·53	16·42	9·69	92·52
11- 1-39	10·34	17·57	9·76	93·00
18- 1-39	12·22	13·12	6·05	93·14
25- 1-39	10·73	17·79	8·94	94·50
1- 2-39	9·7	17·21	7·73	92·93

TABLE IV—*Cynodon dactylon.*

Date of Collection.	Osmotic Value.	Percentage of Sap.	Percentage of Soil Moisture.	Percentage of Water in Sap.
26-10-38	10·07	14·29	8·68	93·12
2-11-38	13·03	20·56	6·91	92·33
9-11-38	13·75	19·71	4·41	91·94
16-11-38	15·49	22·73	3·42	92·94
23-11-38	21·03	12·20	2·18	89·42
30-11-38	19·40	13·23	2·25	90·23
7-12-38	13·08	11·50	8·06	92·39
14-12-38	12·21	16·79	9·85	93·81
21-12-38	10·90	20·00	9·25	93·50
28- 1-39	14·75	12·23	7·15	94·59
4- 1-39	12·03	12·34	10·43	92·08
11- 1-39	12·80	11·34	8·24	91·65
18- 1-39	13·64	14·73	6·32	91·66
25- 1-39	12·57	15·07	9·05	92·48
1- 2-39	10·47	16·18	7·83	93·59

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A CONTRIBUTION TO OUR INFORMATION ON GRASS BURNING

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With 5 Text Figures.

Read 7 July, 1939.

INTRODUCTION.

Since the beginning of farming in South Africa, the controversy on the relative merits and demerits of the burning of the veld has raged.

The main purpose of this paper is to describe briefly some experiments on burning which are being carried out on the High Veld and near Pretoria, and the general information which has been gathered from literature on the subject.

EXPERIMENTAL WORK.

Experiments at Crescent Creek, Milner Park, Johannesburg

This experiment is approximately 5,600 square yards in area, and is divided into three plots, A, B and C. Before 1931 the area had been grazed slightly and burnt practically every year. In July, 1931, the whole area was burnt, and since then plot B has been protected from fire entirely, plot C has been burnt every year at the end of June, and plot A was burnt in 1932 and every alternate year since then.

The objects of this experiment were to discover what changes took place in the floral cover in the plots which were subjected to different burning treatments, and to find out what effects fire had on the physical and chemical composition of the soil.

Comparing the condition in 1938 with that of 1933, it appears that the alternate year burning has had very little effect on the cover of the plot, that the yearly burn has improved the plot in that there has been an increase in the amount of *Themeda triandra*, and that complete protection from fire has had a detrimental effect, in that *Themeda triandra* and some of the other grasses are dying out and various dicotyledons are appearing in the bare places. Furthermore, there is much old growth, forming

a heavy hamper of dry grass which would make the plot unsuitable for grazing purposes.

Phenological records were kept regularly throughout 1937 and 1938. From these observations it appears that burning causes the monocotyledons, other than the grasses, to shoot and flower much earlier in the season.

The grasses flower earlier in the burnt plots, but the actual leaf growth is much less than in the unburnt plots.

It appears that firing does not have a permanent effect on the phenological conditions in the area, but it affects the plot for the season after the fire only. The chief differences are to be noted from July until the end of November, after which time most of the grasses are in flower in all the plots.

Analyses of the Soil Conditions in Plots A, B, and C.

1. *Holard Determinations.*

Fortnightly samples of soil were taken at a depth of 9 inches by means of a soil borer along two transects in each plot. The percentage moisture was calculated on the dry weight of each sample.

From the graph (Fig. 1) it will be seen that leaving the plot unburnt for several years affects the soil moisture content most during the dry winter months, when it is higher than in the burnt plots, but towards the end of Summer (cf. April 1937), when the cover is good in all the plots there is very little difference. This agrees with Scott's (1934) observations in Tanganyika and Aldous (1934) in America.

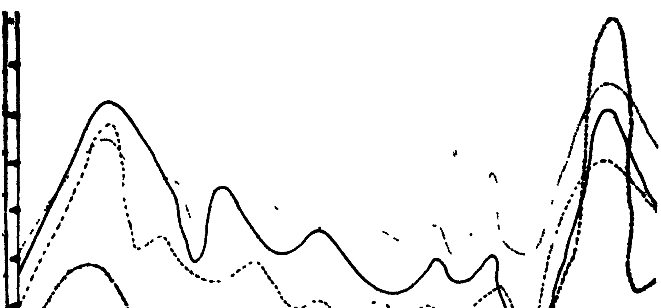

Fig. 1.—Graphs showing the Percentage Moisture of the Soil at 9 inches in Plots A, B, C, and the Rainfall from March, 1937, to January, 1938. Crescent Creek.

———— Plot C—Burnt annually

. . . . . . Plot B—Control.

–.–.–. Plot A—Alternate year burn.

—··—··— Rainfall

From the results obtained by E. P. Phillips (1919), it is evident that in the burnt plots the percentage moisture rises higher immediately after rain, but sinks more rapidly than it does in the unburnt plot. The results from the Crescent creek experiments during October and December show that, although the rise in the burnt plots in greater, relative to the previous holard, it is not actually greater than the holard in the control plot. Furthermore, it depends largely on the type of rainfall and run-off as to whether the rise will be great. The figures agree with those of E. P. Phillips (1919) in that the loss of moisture after rain is greater on the burnt plots.

2. Organic Matter.

The samples for these determinations were taken down two transects in each plot, from the surface to a depth of 1½ inches. Sixty samples were taken before the burn and another sixty after the burn. The percentage organic matter was determined by a method of incineration, and calculated on the dry weight.

From the results obtained it seems evident that over a period of six years fires have had very little effect on the amount of organic matter in the soil, or rather, that protection from fire has led to practically no increase in organic matter.

The amount of undecayed organic matter on the surface of the soil was collected from 2 ft. by 2 ft. areas in each plot. The results were:—

Plot A.	Plot B.	Plot C.
Burnt in alternate years.	Not burnt since 1931.	Burnt annually.
16·12 gms.	248·74 gms.	11·60 gms.
19·50 ,,	468·70 ,,	7.30 ,,

It is evident that this would eventually make a difference in the soil composition, but at present it acts only as a covering, helping to conserve moisture, but it appears also to be preventing the growth of seedlings, and causing some of the grasses to die out. Actually Aldous (1934) found that over a five-year period burning did not cause any decrease in organic matter. The general opinion on this subject, Scott (1934), Staples (1929), Barnette (1930), Thompson (1936), is that burning causes a reduction in organic matter in the soil.

3. Hydrogen Ion Content.

The samples for these and all the following determinations were collected in September from the surface to a depth of 1½ inches. The pH determinations were made by the electrometric method. The following were the average results from the three plots:—

	Plot A. Burnt in alternate years.	Plot B. Not burnt Since 1931.	Plot C. Burnt annually.
1937, after Plot C had been been burnt ...	5·55	5·80	6·70
1938, after Plots A and C had been burnt ...	5·81	5·69	6·35

From the 1937 figures it will be seen that the difference between plots A and B is slight, but there is a definite rise in alkalinity in plot C. It seems, therefore, that yearly burning does change the pH of the surface soil and would eventually affect the lower layers by leaching.

The experiments done by Rice (1932) show similar results.

4. Nitrogen Determinations.

These determinations were carried out by the Kjehldahl method. The average results were:—

Plot A.	Plot B.	Plot C.
0·190%	0·212%	0·116%

The differences between plots A and C and the control plot B are regarded as significant, although the loss of Nitrogen in the burnt plots is very slight.

Aldous (1934) found that there was no decrease in Nitrogen resulting from firing over a period of five years, but the general opinion of workers on this subject, Busse (1908), Staples (1929), Barnette (1930), Thompson (1936), is that firing results in a loss of nitrogen.

5. Maximum Water Retaining Capacity of the Soil.

The maximum water retaining capacity was determined from the formula:

$$\text{M.W.R.C. (per cent.)} \; \frac{\text{weight of water retained x 100}}{\text{weight of dry soil used}}$$

The mean results were:—

Plot A.	Plot B.	Plot C.
79·57%	91·33%	72·57%

The difference between the mean for the control plot and the means for the two fired plots is appreciable. It seems, therefore, that firing results in a change in the composition of the soil to a certain extent.

6. Colloid Determinations.

These determinations were carried out according to the Boyucous' (1930) Hydrometer method.

The mean results were:—

Plot A.	Plot B.	Plot C.
34·4%	39·9%	40·8%

Although there is a certain amount of difference between plots A and C, it cannot be due to the effects of the fire as these plots have both been burnt.

7. *Soluble Salts in the soil.*

No conclusions could be drawn.

Conclusions from Soil Analyses Results.

1. The effect of fire on the pH, soluble salts, and colloids over a period of six years has been very small or there has been no effect at all.

2. After many years the organic matter might increase if the area were left unburnt, but the benefit derived in this respect would be of doubtful value as the control plot is deteriorating in pasture qualities. These views agree with those of Vincent (1935) who, after thirty years of experience, holds that the charges of improverishment of the soil are unproved, and that burning with discretion is one of the few methods available for improving the quality of the herbage and the botanical composition of the area.

3. There is a slight loss of nitrogen. Grasses which are grazed heavily and then shoot rapidly again might exhaust the nitrogen supply to a greater extent than burning does.

Observations on Run-off and Erosion.

During several heavy downpours the run-off was greater on plot C than on the other two plots, but although this run-off resulted in loss of water, it did not carry a great quantity of surface soil away. Most of this heaped against the grass tussocks. Had grazing been carried out, the run-off and erosion would have been increased.

From December onwards when the growth is luxuriant, the run-off is no longer noticeable.

Seasonal Burn Experiments Carried Out at Frankenwald, the Botanical Research Station of the University of the Witwatersrand.

The object of these experiments is to ascertain the effects of seasonal burning in " purple veld." (Previously undisturbed climax grass veld.)

Experiment 1.—Burns are carried out monthly from May to October, and there is an unburned control plot.

Phenological Observations.—From regular phenological observations it appears that there is not a great difference between the plots burnt in May and in June. The plot burnt in July makes better progress in the Spring than May and June burnt plots. In these three plots one notices a great number of Spring flowers when the grasses start shooting. In the August plot very

few flowers are ever seen as they have not started flowering before the burn, and the fire burns the plants down just before flowering. In September and October plots flowering occurs before the burn takes place, but never to such an extent as in the plots burnt earlier in the season.

It is to be noted that the grasses which shoot early, and are at first vigorous in growth, come to a standstill if there is a drought, and take longer to recover after the rains than those which shoot later.

The grasses start shooting well in August, but those on the burnt plots suffer severely from late frosts. The grasses on the September and October plots do not suffer to the same extent, being protected by the old• growth, but on the other hand the early growth in these plots is destroyed at the time of firing.

Early rains followed by drought lead to the withering of the shoots on the burnt areas. This does not happen on the control plot as there is a greater reserve of moisture.

Results Obtained from Quadrat Figures.

In 1934 and 1937, metre quadrats were mapped out (Density List method). From these it is evident that the changes in cover have been comparatively small.

In the control plot, although the quadrat results show no great changes in the cover of *Tristachya hispida*, on a superficial survey it appears that *Tristachya hispida* has increased greatly. This apparent increase is due to the large number of old dry leaves of *Tristachya hispida* covering the plot. It is probable that in a few years time there will be a decrease in *Tristachya hispida* as it is evident that the grass is beginning to suffer from the heavy top covering, and no seedlings are coming in.

Temperature of the Burns.

It was decided to take readings of the temperature at the bases of the grass tussocks as the fire passed over them. This was carried out by means of a Micro-Thermo-Potentiometer circuit. Two Thermo-couples were inserted at the bases of the grasses, and the readings were taken at two minute intervals before, during and after the fire had passed over. From the graphs (Fig. 2) we can see that when the fire passes over the grass the actual temperature is high, going above 600 C., but that it rapidly falls back to the normal temperature, usually in about 6 minutes.

As regards the soil temperatures during the burn it was found that there is little rise in temperature even at a depth of only ·2 inch.

From these results it appears that the actual temperature of the burn has little direct effect on the grasses if they are burnt during late Autumn or Winter, for the fire merely burns the old dry grass and does not affect the root stock. The chief

effects of the burning are not directly due to the heat of the fire, but changes result from the removal of the top hamper and the subsequent insolation which takes place during the dry Winter months.

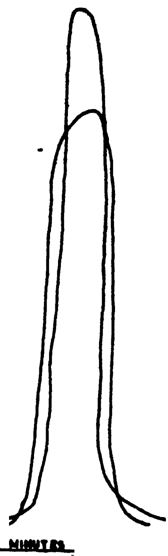

Fig. 2.—Graph showing the Change in Temperature at the bases of Two Tussocks of Grass during the August Burn.

Differences in growth of certain grasses in burnt and unburnt areas.

One of the most striking phenomena is the difference between the form and size of the grasses as they start shooting in the burnt and in the control plots.

It was found in the cases of *Tristachya hispida* and *Harpechloa falx* that shooting starts earlier in the burnt plots, but that when these grasses shoot in the control plots the leaf growth is more rapid and more luscious. These grasses flower at a much earlier stage in the burnt plots. The difference in growth is shown clearly in the photographs (Figs. 3 and 4).

Discussion on the number of New Shoots in Burnt and Unburnt Areas in the Spring.

Various controversial points of view have been put forward as to whether the grass on the burnt plots shoots earlier than on the unburnt plots. Scott (1934), Bews (1929) Hensel (1923) Phillips (1936), hold that shooting takes place earlier in the burnt plots due to the maximum temperatures being higher on the burnt than the unburnt areas.

Fig 3.—*Harpechloa falx*
A—From Burnt Plot
B—From Unburnt Plot

Fig 4.—*Tristachya hispida*
A—From Burnt Plot
B—From Unburnt Plot

It was attempted to arrive at some conclusion based on a mathematical analysis of the question. New shoots in various experimental plots were counted.

The observations on "unburnt" areas were taken at random from plots which are normally burnt every year, but were unburnt at the time of counting. Those from "burnt" plots were taken from areas which are normally burnt every year and were burnt at the time of counting. Those from "control" were taken from plots which had not been burnt for over four years.

The observations were made by choosing specimens of the required species at random, and then counting the number of blades of grass shooting in each particular tussock. By this method it was hoped to obtain a selection of large and small tussocks. The counting was carried out in August when the grasses had just started shooting and, on superficial appearance, the burnt plots were green and the unburnt plots were a yellow-brown showing no signs of greenness.

The results lead one to the conclusion that the effects of fire on the amount of shooting in Spring on burnt and unburnt areas are not significant, but that there is a difference between the plots which have been unburnt for a number of years and those which are burnt annually.

Seasonal Burn Experiment—2

In this experiment there are 40 plots. Four are unburnt controls. The remaining plots are burnt between the 20th and the 25th of each month (three plots per month). These plots are randomised.

From the phenological observations on this experiment it appears that the plots burnt in February, March and April put forth quite extensive new growth after the fire. Some of the grasses such as *Tristachya hispida* come into flower before the Winter. This new growth is cut down by frost, and in the Spring these plots remain dry and brown much longer than those which are burnt during May, June and July.

Burning and Grazing Experiments.

Combined burning and grazing experiments have been set out in order to distinguish the effects and relationships of burning, grazing and trampling over varying periods.

In the heavily grazed plots fire plays an unimportant rôle, as there is usually not sufficient cover to burn, and, on the whole, even in the lightly grazed areas the grazing masks the effect of the fire.

Seasonal Burn and Graze Experiment.

The object of this experiment is to determine the most suitable times for burning and grazing. Burning is carried out in July, August and September; three plots are burnt in each month One of each of these is grazed moderately as soon as the grass is long enough (Fig. 5. A1, A2, A3, A4), the second of each of these is grazed moderately from midsummer onwards (B1, B2, B3, B4). The third is grazed moderately in midsummer. In the latter there are no separating fences between the monthly burns and the cattle should show any choice for veld burnt at different seasons (C1, C2, C3, C4).

	Burnt in July	Burnt in August	Burnt in Sept.	Burnt in Sept.
Grazed in Mid-summer	C1	C2	C3	C4 P.N.K.
Grazed in Mid-summer	B1	B2	B3	B4 P.N.K.
Grazed early in Season	A1	A2	A3	A4 P.N.K.

Fig. 5.—Seasonal burning and grazing experiment, Frankenwald.

In this experiment the plots grazed in mid-summer are more rank as the grass has time to grow before being grazed. This is particularly evident in the plots burnt early in the year: in which the cattle tend to leave the coarser grasses, whereas in the plots grazed soon after the burn this selectivity was not evident.

SEASONAL BURN EXPERIMENT, DRYLANDS, GROENKLOOF.

In this experiment it appears that in the control, unburnt plot, *Loudetia simplex* and *Cymbopogon* spp. are increasing and *Themeda triandra* is decreasing; also the flowering of the grasses is much later than in the burnt plots, but the leaf growth is more luxuriant.

GENERAL VIEWS, OBSERVATIONS AND CONCLUSIONS CONCERNING GRASS BURNING.

Since prehistoric times burning of the vegetation has taken place in South Africa, but it is only during the latter part of the nineteenth century that any serious thought is given to the good or harm resulting from the practice of burning.

The greater mass of opinion, Adamson (1934), Bennett and Chapline (1928), Busse (1908) Compton (1924), Nicholls (1901), Scott (1934), J. F. V. Phillips (1931a), Haines (1926), shows that burning results in deterioration of the soil owing to reduction in humus, nitrogen, water supplying power of the soil, loss of irrigation water and leaching of total salts. This leads to impoverishment of the cover and results in erosion. Other workers, Aldous (1934), Vincent (1935), hold that this impoverishment is not as great as some would make it appear.

By some, Consigney (1937), Sim (1920), Marloth (1924), Pillans (1924), it is held that it is not essential to burn and that firing causes actual deterioration in the grass cover, but the greater number, Bews (1918), Bews (1929), Busse (1908), Galpin (1936), Gill (1936), Hensel (1923a), Rowland (1936), Schonland (1927), Vincent (1935), hold that in many cases in order to obtain satisfactory grazing, despite the loss in soil fertility, it is essential to burn.

Those who are against burning put forward the argument that, if it is necessary to burn an area, that area of the country should be devoted to tree growth. Against this is the fact that it is often of greater economic value to retain grasslands, for further development in the succession often leads to a dense growth of scrub and stunted acacias, which, beyond assisting in soil conservation, cannot be used economically. Galpin (1936).

With our present information on the subject, the final conclusions are that burning should be prohibited in all catchment areas, along streams and in places where the gradient would lead to serious run-off and erosion.

In the greater part of the grazing areas of the Union it is necessary to burn in order to keep the succession at the most

satisfactory stage, but the local conditions prevailing in a particular area should be studied, and, according to amount of rainfall and type of cover, the frequency of burning and the amount of grazing to follow should be decided. It is certain that much harm can be done by injudicious burning and grazing, but similarly deterioration of the veld takes place by withholding fire.

SUMMARY.

1. From the Crescent Creek experiment it has been shown that the plot which was not burnt has deteriorated in grazing quality. The plot burnt every other year has remained in the same condition, and the plot burnt every year has improved in quality. From these observations and the phenological records of all the experimental plots, it appears that burning improves the veld, and that the best time for burning in the highveld areas is late in June or July, but if grazing is being carried out, burning should not take place annually.

2. Analyses of the soil showed that firing over a period of six years did not prove extremely detrimental with respect to the amount of organic matter, nitrogen, total soluble salts, hydrogen ion, and the maximum water retaining capacity of the soil, and that the benefit derived from burning resulting in good or improved pasturage outweighs the losses caused by fires in deterioration of soil composition. .

3. The amount of water lost from burnt areas during rain is greater than that on unburnt areas, and the unburnt areas conserve the water for a greater length of time.

4. The actual temperature of the burn does little harm if the fire takes place during winter. It is the following months of exposure to the sun which cause the greatest amount of damage. Thus, whether the veld is kept short by burning or grazing, it has, in either case, to suffer the severe months of insolation, and burning probably causes less damage than heavy grazing.

5. There is often a great difference in the growth of certain grasses in the control plots and the burnt plots. The growth in the control being far more luxuriant, but unfortunately unattainable owing to the hamper of dry leaves.

6. From statistical analyses of the amount of shooting in Spring, it appears that there is very little difference between burnt areas, and areas which are burnt frequently but are unburnt at the time of analyses, but that there is more shooting on both these areas than on areas which have been protected from fire for several years.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVI, pp. 283-285, December, 1939.*

SEX-LINKED INHERITANCE IN *CARICA PAPAYA* L

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Read 7 July, 1939.

Hofmeyr (1938a: 332, 1938b: 302) reported a linkage of ± 30 per cent. between the sex factors M_1, M_2 and m and the genes for yellow vs. white flower colour, Y,y. In these papers an hypothesis for the determination of the three sex types of the papaya on a factorial basis, was presented. These factors are thought to be allemorphic, M_1 determining maleness, M_2 bisexualism and m femaleness. Hence the staminate plant is M_1m, the hermaphrodite M_2m and the pistillate plant m m. The limited results available at that time suggested that purple vs. non-purple stem colour, P,p are inherited independently from sex. The three-point tests involving the sex factors, flower and stem colour genes, presented in this paper, will show that the genes P,p are sex-linked.

Three-point Tests Involving the Sex Factors M_1, M_2, m and the genes Y,y for flower colour, and P,p for stem colour.

In Table 1A and 1B the results are reported respectively, of the backcross, non-purple, white flowered, pistillate plant with a purple, yellow flowered hermaphrodite, e.g. $\frac{m\ y\ p}{m\ y\ p} \times \frac{M_2 y\ P}{m\ Y\ p}$; and of the backcross, non-purple, white flowered pistillate plant with a purple yellow flowered staminate plant, e.g. $\frac{m\ y\ p}{m\ y\ p} \times \frac{M_1 Y\ p}{m\ y\ P}$.

Table 1: A—Results of the cross $\frac{m\ y\ p}{m\ y\ p} \times \frac{M_2 y\ P}{m\ Y\ p}$.

B—Results of the cross $\frac{m\ y\ p}{m\ y\ p} \times \frac{M_1 Y\ p}{m\ y\ P}$.

	Non-Cross-over Classes		Cross-over Classes					
			Region 1		Region 2		Regions 1 and 2	
A	M_2y P	m Y p	M_2Y p	m y P	M_2y p	m Y P	M_2Y P	m y p
	70	50	20	21	21	14	1	1
B	M_1Y p	m y P	M_1y P	m Y p	M_1Y P	m y p	M_1y p	m Y P
	55	59	20	23	10	15	5	—

From the data presented above the following linkage values are obtained:—

	M m Y y	Phase	Y y P p	Phase	M m P p	Phase
Pist. x Herm. ...	$21{\cdot}7 \pm 2{\cdot}0$	Repuls.	$18{\cdot}7 \pm 1{\cdot}9$	Repuls.	$38{\cdot}4 \pm 2{\cdot}3$	Coup.
Pist. x Stam. ...	$25{\cdot}7 \pm 2{\cdot}2$	Coup.	$16{\cdot}0 \pm 1{\cdot}8$	Repuls.	$36{\cdot}4 \pm 2{\cdot}4$	Repuls.

Here M may represent either M_1 or M_2 depending on the cross studied.

It will be noticed in Table 1A that there are 112 hermaphrodite and 86 pistillate plants, whereas, according to the results presented by Hofmeyr (1938c) equal numbers should be expected. The deviation from equality is $13 \pm 4{\cdot}75$ and the P value is $\pm{\cdot}05$ which being on the border line of significance indicates that some other factors than random sampling might be responsible for this deviation. A further study shows a marked deficiency of pistillate plants in the m Y p and m Y P classes, the cause of which being not clear at present. In Table 1B the number of staminate and pistillate plants are respectively 90 and 97, which is a close approximation of expectancy. The segregation in the individual classes is apparently normal. Notwithstanding this disturbing factor in the first cross, the agreement of the cross-over values between the factors studied in the comparative classes of the two crosses listed is reasonably close, and their respective differences may be shown to be statistically insignificant. The results indicate that P,p are linked with the sex factors M_1, M_2, m and are not inherited independently from them as Hofmeyr (1938a) has previously reported.

If it is permitted to average the linkage results observed in the two crosses reported above the following approximate values are obtained:—

Linked factors.	Cross-over-values.
M_1, M_2, m with Y_1y	23·7%
Y,y with P,p	17·3%
M_1, M_2, m with P,p	37·4%

From these results the following order of the genes and their relative positions on the " sex chromosomes " is suggested:—

$$\underline{M \quad 23{\cdot}7 \quad Y \quad 17{\cdot}3 \quad P}$$

M represents the sex factors M_1, M_2 and m.

These linkage studies suggest that the association of the " sex chromosomes " are apparently normal over a length of approximately 40 units during meiosis in the microsporogenesis of both staminate and hermaphrodite plants.

SUMMARY.

The results indicate that the genes P,p for purple vs. non-purple stem colour are fairly closely linked with the Y,y genes for yellow vs. white flower colour, and comparatively loosely linked with the sex factors M_1, M_2, m.

Results of the following three-point tests are reported:—

$\dfrac{m\ y\ p}{m\ y\ p} \times \dfrac{M_2 y\ P}{m\ Y\ p}$ and $\dfrac{m\ y\ p}{m\ y\ p} \times \dfrac{M_1 Y p}{m\ y\ P}$, which establishes these genes in the following order M 23·7 Y 17·3 P.

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SEX REVERSAL IN *CARICA PAPAYA* L

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ABSTRACT.

The term " sex reversal " as applied in this paper does not refer to change of sex of the individual as a whole, but to a localised change in individual flowers borne on pistillate, staminate and hermaphrodite trees.

SEX REVERSAL IN STAMINATE TREES.

A change of sex in the flowers of staminate trees is of frequent occurrence, and, as observations have shown, is apparently induced by both genetic and environmental factors. This supports similar studies conducted by Higgins and Holt (1914). General observations indicate that the type of sex change may be controlled genetically.

SEX REVERSAL IN HERMAPHRODITES.

Five types of flowers are commonly produced on hermaphrodites (Hofmeyr, 1938), namely:— Type I. (normal pistil, 10 stamens), Type II. (normal pistil, 5 stamens), Type III. (normal pistil, no stamens), Type IV. (pistil usually normal, variable number of stamens; the filaments of some may be fused with the wall of the ovary) and Type V. (abortive pistil, 10 stamens). Storey (1937) and Hofmeyr (1938) have indicated that there is a direct relation between the type of flower and the shape of the fruit which develops from it. Hence an examination of the whole crop of fruit on the tree at the end of the season should give a good record of the types of flowers which had developed successively throughout the season. Since Type V. flowers are wholly staminate corresponding vacant spaces are left where they had been formed. Now if flowers with 10 stamens (Types I. and V.) could be regarded as exhibiting a tendency towards maleness, and are signified by M and those with less than 10 stamens (Types II., III. and IV.) towards femaleness and are signified by F, it was found that 76 per cent. of the flowers produced during the first half of the growing season were of the F type, and 24 per cent. of the M type. Similarly, 83 per cent. of the flowers of the second half of the season were of the M type and 17 per cent. of the F type. Since conditions are more conducive to the stimulation of active growth during the first half of the growing season than during the second half, it could be concluded that favourable growing conditions are generally more advantageous for the development of flowers with a female-like tendency and less favourable for the development of flowers

with a male-like tendency, and vice versa. The critical stage of flowerbud formation is of comparatively short duration, hence it is conceivable that sudden changes in the environment may overrule general growing conditions and affect the basic physiology of flowerbud formation in such a way that M type flowers may be formed in close proximity to F type flowers at any time of the season. This may serve to explain the variability in the types of flowers produced throughout the season.

Sex Reversal in Pistillate Plants.

Probably the first case of sex reversal in the flowers of pistillate plants of the papaya recorded is reported in this paper. The number of pistillate plants which showed sex reversal in some of their flowers were nineteen, and fifteen of this number were found in closely related pedigrees. This would suggest that genetic factors might have been responsible to induce sex change in the flowers of pistillate trees. Such factors are probably recessive in nature, since sex change have only become evident after the second and third generations of inbreeding. The frequency of the occurrence of flowers showing sex change was found not to exceed three per tree, and has only been observed during the first half of the growing season. Sex change in such flowers is very incomplete and may be localised to only one section of the flower, so that unsymmetrical flowers with usually only one stamen and occasionally up to three stamens are developed. In some cases the filaments of the stamens are thickened at the base, and may show various transition stages into carpels. The general impression obtained is that sex reversal in the flowers of pistillate trees is very weak and has proceeded only a short way towards the production of hermaphrodite flowers, which normally has five or ten stamens.

Conclusion.

Sex change as well as the type of sex change in the flowers of pistillate, hermaphrodite and staminate trees are apparently affected by both genetic and environmental factors. In both staminate and hermaphrodite plants the change towards femaleness is encouraged by favourable growing conditions, while poor growing conditions are favourable for the production of maleness. Studies have shown that, with respect to change of sex in the flowers of the three sex types, the pistillate plant is by far the most stable and the hermaphrodite is very unstable, while the staminate plant is intermediate with respect to its stability.

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SOME SUGGESTIONS ON THE MECHANISM OF SEX DETERMINATION IN *CARICA PAPAYA* L

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Abstract.

According to the factorial hypothesis of sex determination in *Carica papaya* L developed by the author (Hofmeyr, 1938, a, b, c), m determines femaleness, M_1 maleness and M_2 hermaphroditism. These factors are apparently allelic. Hence the pistillate plant = m m, staminate = M_1m and the hermaphrodite = M_2m.

the following ratios were obtained in crosses:—

m m x M_1m	=	1 M_1m	:	1 m m		
M_1m (selfed)	=	2 M_1m	:	1 m m		
m m x M_2m	=	1 M_2m	:	1 m m		
M_2m (selfed)	=	2 M_2m	:	1 m m		
M_2m x M_1m	-	1 M_2m	:	1 M_1m	:	1 m m.

The expected M_1M_1, M_2M_2 and M_2M_1 genotypes did not appear in the corresponding crosses listed above, and hence are assumed to be non-viable. This is supported by a letter received from Mr. W. B. Storey of the Hawaiian Agricultural Experimental Station, in which he states that he found in a preliminary study of ovules and seeds of staminate and hermaphrodite plants that 25 per cent. of them were devoid of embryos, whereas the seeds of pistillate plants were nearly 100 per cent. viable. He suggests two probable explanations for the failure of an embryo to develop in the 25 per cent. representing the M M genotypes:—

(1) That a male nucleus carrying M fails to fertilise the egg carrying M after it has been discharged into the embryo sac.

(2) That the M M zygote itself is killed by some lethal effect at a very early stage of its development.

Lindsay (1930) found no evidence of an unequal pair of chromosomes in *Carica papaya*, the haploid number of which is 9. She observed a regular separation of equal pairs of chromosomes on both heterotypic and homotypic spindles. Hofmeyr (1939a)

found that crossing-over was apparently normal in the "sex chromosomes" for a length of approximately 40 cross-over units, which indicates that these chromosomes are homologous for a comparatively large section.

The Genic Balance Hypothesis.

An hypothesis is proposed on the basis of genic balance of male and female determiners in the "sex chromosomes" (the chromosomes bearing M_1, M_2 and m will be referred to, forthwith, as sex chromosomes) and the autosomes. It is assumed that the female determiners predominate in the sex chromosomes and the male determiners in the sum-total of the autosomes. It is further assumed that M_1 and M_2 really represent an inert or inactivated section of the sex chromosomes, but that the inert section represented by M_1 is of slightly greater dimensions than that represented by M_2. Should this be the case it is possible to visualise that genes vital to life have been eliminated in the M_1 and M_2 sex chromosomes so that M_1M_1, M_2M_2 and M_2M_1 individuals would be unable to survive, as has been recorded above. On the other hand M_1m and M_2m would be perfectly viable as a result of the presence of an m sex chromosome in each case.

The balance of male and female determiners may be illustrated by assigning the following arbitrary values to the different sex chromosomes and the autosomes:—m = 25, M_1 = 21, M_2 = 22 and 47 for the sum-total of the autosomes. The values recorded for the sex chromosomes represent the degree with which the female determiners would exceed the male determiners in these chromosomes and vice versa for the autosomes. Hence the balance for the pistillate plant would be 50-47 = 3 in favour of femaleness; the staminate plant, 46-47 = 1 in favour of maleness; the hermaphrodite being an intermediate type would be, 47-47 = 0, which is an even balance of male and female determiners. Hofmeyr (1939b) reports that the pistillate plant is sexually the most stable, followed by the staminate and the hermaphrodite plants in lesser degree in the order indicated. Hence the values recorded above reflect the relative stability of these sex types. The hermaphrodite being at the threshold value of 0 would be pushed comparatively easily in either the direction of maleness or femaleness when subjected to environmental changes. The staminate plant having a balance of 1 in favour of maleness would be sufficiently near the threshold value to render it sexually more unstable than the pistillate plant with a balance of 3 in favour of femaleness, and hence more susceptible to sex changes in its flowers than the latter. Since observations (Hofmeyr 1939b) have shown that the staminate plants of different pedigrees may be different, genetically, with respect to the frequency of sex change in their respective flowers, it seems possible that genetic factors might be instrumental to push the balance nearer or further away from the threshold value resulting

respectively, in lesser or greater sexual stability. Similar reasonings are applicable also to differential sex changes within each of the pistillate and hermaphrodite sex types.

It should be stated finally, that it would be necessary to assume that crossing-over does not occur within the so-called inert regions of the M_1 and M_2 sex chromosomes. It stands to reason that, following the reasoning of this hypothesis, if crossing-over did occur, all kinds of sex intergrades would be expected to appear in the progenies of the various crosses listed above. Apparently this is not the case.

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THE XYLEM ANATOMY, RELATIVE WATER CONDUCTIVITY AND TRANSPORT OF DYES IN CITRUS STEMS

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Read 7 July.

With 2 Graphs and 8 Text Figures.

I. Anatomy.

1 *Introduction and Literature.*

Very little is known of the anatomy of various citrus species. Most of the anatomical descriptions date from the end of the nineteenth century and are not easily accessible. The most important of these, according to Webber and Fawcett (1935) are those of Moeller (1876), Penzig (1887), Mitlacher (1901), Piccioli (1906) and Burgerstein (1908). Solereder (1908) described the glands of Rutaceae and the xylem of *Citrus aurantium* in detail. The latter was also described by Wiesner in 1928. Webber and Fawcett in 1935 published a detailed description of *Citrus sinensis*, which included the results of other investigations besides their own.

It is not known to what extent the anatomy of the Citrus species differs from one another in various parts of the world. From the descriptions of Moeller, Penzig, Piccioli, Burgerstein and Solereder, Webber and Fawcett conclude, "that structural differences between the woods of various species of citrus are not well marked, since those that are pointed out are of a nature now known to be influenced by environment." Wide variations have been found in the xylem of a single citrus species, not only in different areas, but in different trees in the same area, different branches of the same tree, and in different parts of the same stem. From the literature, therefore, it is impossible to compare the anatomy of the various citrus species, since there is no information on the anatomy of each species under comparable conditions.

The study of anatomy, particularly of the xylem and phloem, is important in connection with the transport of water and nutritive substances. It is also of importance in connection with the stock-scion effect and the problem of incompatability. For that reason a study was made of the xylem anatomy of rough lemon and sour orange (as examples of stocks) and grapefruit (as an example of a scion).

2. *Xylem Anatomy of Rough Lemon* (*Citrus limonia*, Osbeck).

(a) *Materials and Methods.* — The stems used for the anatomical studies were obtained from rough lemon trees, grown from seed obtained from the Cape Province and planted at the University of Pretoria in April, 1936. They were grown in tanks 20 inches in diameter and 24 inches deep. In October, 1938, the trees were cut back to a height of 12 inches above the ground. In January, 1939, ten of the young shoots which had grown out were selected. The thickness of the stems varied from ·61 to ·70 cm. with an average thickness of ·64 cm. The material was used fresh, coloured with a solution of iodine in potassium iodide. Fifty measurements were made of the cells of each tissue in each of the ten shoots, giving a total of 500 measurements for every type of cell. The cells were examined and drawn under the high power of the microscope (x660) with the aid of a camera lucida. The drawings were then measured. To obtain a reliable average, particularly of the xylem vessels, all the elements in a given area, extending from just outside the pith to the cambium, were measured. Because of their irregularity, the vessels immediately adjacent to the pith were not included. This was done in a number of sections of the same shoot.

To determine the length of the xylem vessels, Malhotra's method (1931) was followed. Stems ·8 to 1·3 cm. in thickness and 76 to 124 cm. in length were used. These were cut to a length of 50 cm., and mercury under a pressure of 100 cm. was forced into the base of the stems. After an hour, lengths of ·2 to ·5 cm. were cut in succession off the top of the stems, at intervals of 15 to 30 minutes between each cut, until drops of mercury first appeared. The length of the stem at this stage was equivalent to the maximum length of the xylem vessels in the stem. It was assumed that the mercury was forced up a vessel until stopped by a cross wall.

To obtain maceration of the various tissues, tangential longitudinal sections of the stem were heated in *Eau de javelle* or boiled in concentrated ammonia solution.

(b) *Description.*—The xylem consists of vessels, fibres and parenchyma (Fig. 1); tracheides are absent. The distribution of the xylem vessels is irregular; the majority are single but they also occur arranged in radial rows of 2 to 5 or in groups of 2 to 4. The average number of vessels per sq. mm. is 48 (17 to 107). The number of vessels varies from stem to stem, but there is also considerable variation between the number in different areas of the same section. Fibres make up the ground tissue of the stem; the larger fibres usually arranged in radial rows, and the smaller fibres less evenly distributed between them (Fig. 1); generally speaking, there is little xylem parenchyma in comparison with the number of fibres. The parenchyma

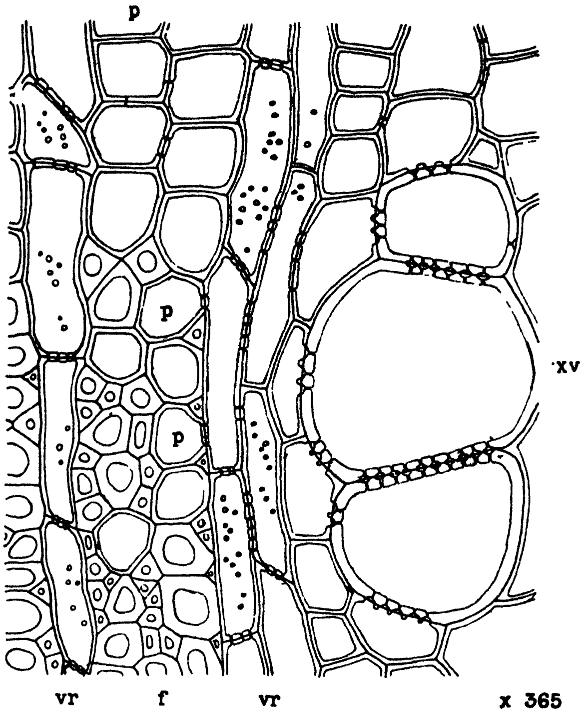


Fig. 1.—Xylem of Rough Lemon. Transverse section. xv, xylem vessels; p, parenchyma; f, fibres; vr, vascular ray.

occurs around the xylem vessels (paratracheal), singly or in groups between the fibres (diffuse), but most commonly in concentric bands 2 to 5 cells in thickness. The bands of parenchyma sometimes give the impression of forming the end of an annual ring, but in this case this is not necessarily so. The xylem rays are uniseriate or multiseriate, and usually only up to 4 cell rows in width and up to 20 cells in height. The xylem vessels are either directly in contact with the vascular rays or indirectly through the xylem parenchyma.

(i) Xylem vessels. The vessels are usually oval in cross section, but may also be circular. When two vessels are in contact the adjoining walls are flattened (Fig. 1). The average radial diameter of the vessels is 50·3 μ (18·8 to 93·6 μ) and the tangential diameter 42·7 μ (19·6 to 83·0 μ). The average diameter is 46·5 μ. The average length of the vessel segments is 54·3 μ (24·5 to 97·9 μ). The cross wall may be

inclined at any angle from horizontal to nearly vertical (Fig. 2). The perforation is simple. The apertures reach a maximum when the cross walls are approximately horizontal. In such vessels the cross wall is reduced to a narrow border; where the cross wall is steeply inclined the area around the perforation is wide and contains many bordered pits (Fig. 3). The perforation may be oval or circular, and is 16·4 to 33·2 μ in diameter. The wall of the perforation may be either smooth, or indented like that of a bordered pit.

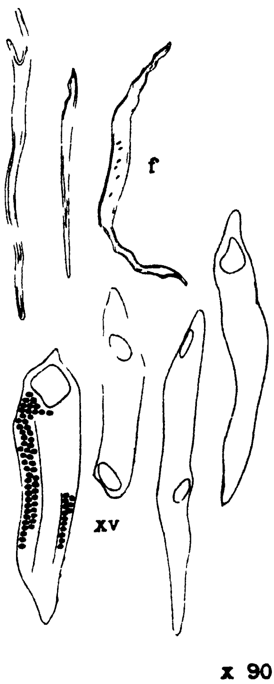


Fig. 2.—Xylem of Rough Lemon. xv, xylem vessels; f, fibres.

The cell walls of the vessels average 3 μ (1·88 to 5·3 μ) in thickness. Bordered pits are present where two vessels are in contact with one another, averaging 3·3 μ (1·5 μ to 6·8 μ) in size, evenly distributed and closely packed. The borders of the pits are circular or angular; the apertures are oval or circular opening into a channel leading to the cavity. Where the vessels

are in contact with xylem parenchyma or xylem rays, half bordered pits occur (Figs. 1 and 3).

The total length of the vessels, determined by Malhotra's method, was found to vary between 27·5 and 48 cm. Malhotra himself found that the maximum length of the xylem vessels of Eureka lemon was 27 cm. and of sour orange 42 cm.

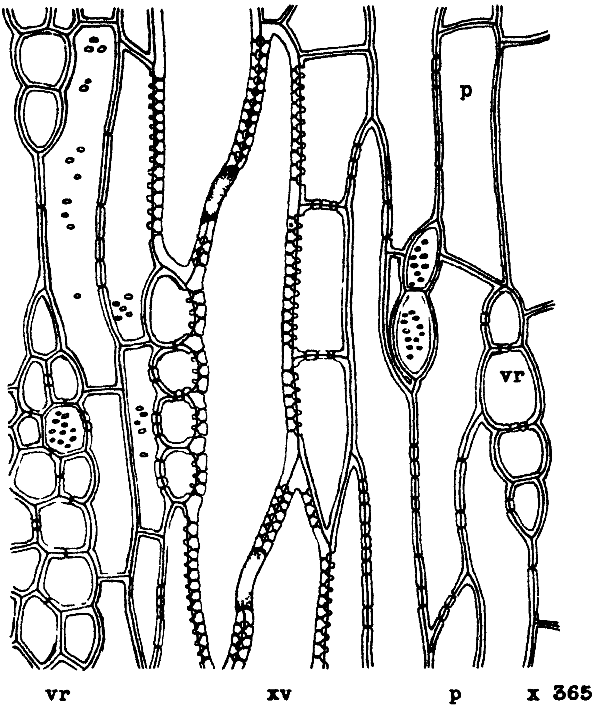


Fig. 3.—Xylem of Rough Lemon. Tangential longitudinal section. xv, xylem vessl; p, parenchyma; vr, vascular ray.

The course of the vessels is usually straight, but branching occurs, usually near the nodes, but also between them. The branching was only found to take place in a tangential direction, but it is possible that branching in a radial direction may also occur. The segment of the vessel to which the branch is attached has, besides the normal perforations in the two cross walls, a perforation in the longitudinal wall where it is in contact with the adjacent segment which forms the beginning of another vessel (Fig. 4). The two segments continue upwards as parts of separate vessels. The branches remain close together in some cases (Fig. 4a); in others they diverge immediately as in Fig. 4b.

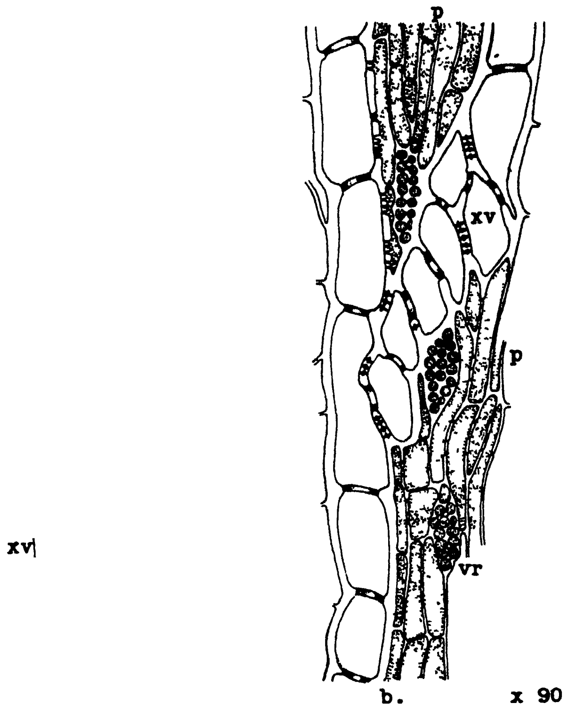


Fig. 1.—Xylem of Rough Lemon Tangential longitudinal section, showing branching of vessels. xv, xylem vessels; p, parenchyma; vr, vascular ray.

(ii) Xylem fibres. The fibres are irregular, both in size and in shape (Fig. 2). The average diameter is 10·4 μ (3·0 to 18·9 μ); the cell walls average 2·4 μ (1·3 to 4·5 μ) in thickness Small crossed pits occur, particularly on the radial walls The average length of the fibres is 153·2 μ (81·6 to 193 μ).

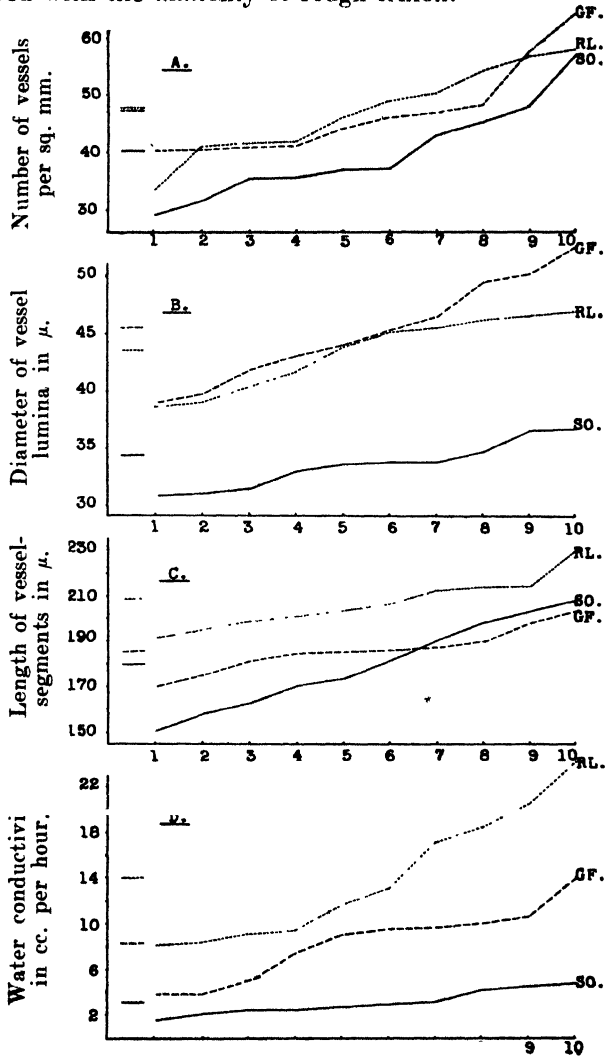
(iii) Xylem parenchyma. The xylem parenchyma is lignified. It usually contains a considerable amount of starch. The average radial diameter is 18·4 μ (8·3 to 35·5 μ) and the average thickness of the cell walls is 1·3 μ (·75 to 2·6 μ). Simple pits are common when xylem parenchyma cells are in contact with one another or with xylem ray cells and are particularly numerous on the radial walls (Figs. 1 and 3).

(iv) Xylem rays. In cross section the xylem ray cells are long and narrow, averaging 53·3 μ (22·7 to 101·2 μ) long and 9·3 μ (2·8 to 21·9 μ) wide. In tangential longitudinal section the cells are oval or circular. The cell walls are lignified and

contain numerous simple pits where they adjoin xylem-parenchyma or other xylem ray cells, and half bordered pits where they are in contact with xylem vessels (Figs. 1 and 3).

3. *A Comparative Study of the Xylem Anatomy in Rough Lemon, Marsh Grapefruit and Sour Orange.*

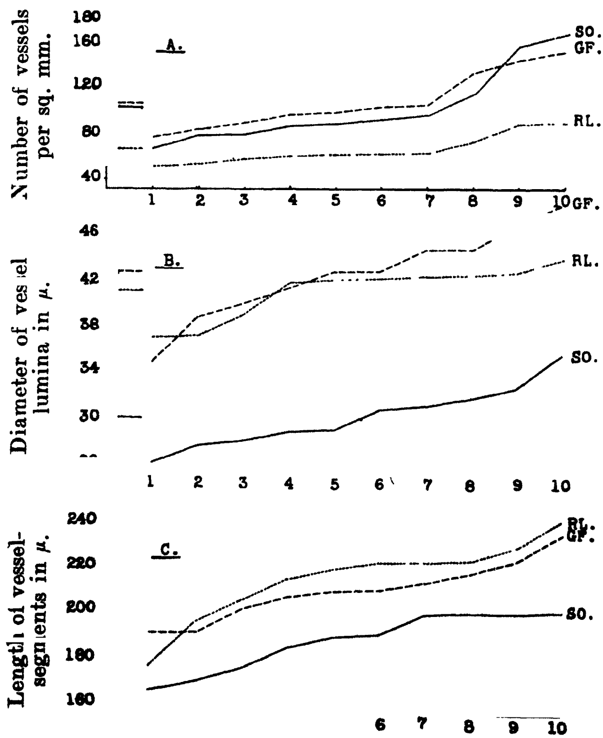
The anatomy of Marsh grapefruit (*Citrus maxina* Osbeck) and sour orange (*Citrus aurantium* Linn) was studied and compared with the anatomy of rough lemon.



Graph 1.—Comparison of Rough Lemon, Grapefruit and Sour Orange from Pretoria. The averages are indicated on the left.

The sour orange stems used for the study of the anatomy were also obtained from trees planted at the University of Pretoria in April, 1936. The trees were grown from seed obtained from Australia, Zanzibar, Cyprus, Florida, Russia, Jamaica and Egypt. As no constant difference was found in the anatomy of the trees from the different areas, no distinction was made between them. As in the case of rough lemon, they were grown in tanks. They received the same treatment as rough lemon, and in October, 1938, were cut back to a height of a foot above the ground. In January, 1939, ten new shoots with an average thickness of ·69 cm. (·58 to ·75 cm.) were selected for study.

Marsh grapefruit stems were cut in January, 1939, also from trees growing in the grounds of the University of Pretoria. The grapefruit were budded on rough lemon stock and were obtained from the Montrose Nurseries, White River, Transvaal, in 1934. The ten stems had an average thickness of ·6 cm. (·53 to ·73 cm.) and were the result of a single season's growth.



Graph 2.—Comparison of Rough Lemon, Grapefruit and Sour Orange from California. The averages are indicated on the left.

For further comparison ten stems of rough lemon, Marsh grapefruit and sour orange were obtained from Riverside, California, through the courtesy of Dr. A. R. C. Haas. The average thickness of the stems of rough lemon in this case was ·79 cm. (·65 to ·89 cm.); of grapefruit, ·69 cm. (·63 to ·75 cm.); and of sour orange ·65 cm. (·58 to ·75 cm.).

Only the number of vessels per sq. mm., the diameter of the vessels and the length of the vessel-segments was determined. The average, minimum and maximum of 50 measurements of each of these was determined for each of the 10 shoots, giving a total of 500 measurements of each for each citrus species. These measurements of Pretoria and California stems are given in the following table, and the average for each of the ten shoots are given in graphs 1, A, B, C, and 2, A, B, C. The stems are numbered 1 to 10 according to the averages in each case, No. 1 having the lowest and No. 10 the highest values.

TABLE I.

		Rough Lemon	Grapefruit	Sour Orange
Pretoria	Number of vessels per sq. mm.	47·7 (17·8—107·1)	47·3 (17·8—116·0)	40·0 (17·8—178·0)
	Average diameter of vessels in μ	43·5 (38·6—47·0)	45·4 (38·9—52·9)	34·4 (30·8—36·9)
	Length of vessel segments in μ	207·4 (102·5—362·6)	186·0 (69·7—340·3)	179·9 (49·2—311·6)
California	Number of vessels per sq. mm.	66·0 (17·8—178·0)	107·5 (26·7- 294·6)	102·3 (17·8—267·8)
	Average diameter of vessels in μ	41·2 (9·0 – 84·6)	42·5 (10·5—110·2)	30·3 (9·0—58·9)
	Length of vessels in μ	214·5 (102·5—356·7	209·2 (102·5—344·4)	186·9 (90·2—307·5)

From the table the following may be concluded:

(1) *Comparison of Rough Lemon, Grapefruit and Sour Orange from Pretoria.*

(a) There are about the same number of xylem vessels per sq. mm. in rough lemon and grapefruit, though the average of rough lemon is slightly higher. In the case of sour orange, the smallest average number of xylem vessels per sq. mm. was found to occur, and there is much wider variation between the minimum and maximum than in the case of rough lemon or grapefruit.

(b) Grapefruit has the largest xylem vessels (the largest average and maximum) and also the greatest variation in size. The xylem vessels of rough lemon are only slightly smaller than those of grapefruit. Sour orange has the smallest vessels, and these also show the least variation in size.

(c) The longest segments of the xylem vessels are found in rough lemon and the shortest in sour orange.

(ii) *Comparison of Rough Lemon, Grapefruit and Sour Orange from California.*

(a) Grapefruit and sour orange have about the same number of vessels per sq. mm., though the average of grapefruit is slightly higher. In both cases there is a wide variation between the minimum and maximum number of vessels per sq. mm. In the case of rough lemon there are considerably fewer vessels per sq.mm., and there is also less variation in the number of vessels.

(b) Grapefruit has the largest vessels (the largest average and maximum) and also the widest variation between maximum and minimum. The vessels of rough lemon are only slightly smaller than those of grapefruit. Sour orange has the smallest vessels and also the least variation in the size of the vessels.

(c) Rough lemon has the longest vessel-segments and sour orange the shortest.

(iii) *Comparison of Rough Lemon, Grapefruit and Sour Orange from Pretoria and California.*

(a) In the case of all three species from California, there are far more xylem vessels per sq. mm. than in those from Pretoria. It is interesting to note that in the case of the material from California, rough lemon has far fewer vessels than grapefruit or sour orange, while in the case of the material from Pretoria, the smallest number of xylem vessels per sq. mm. is found in sour orange.

(b) The xylem vessels of the Californian species are on the average smaller than those of the Pretoria species, but there are far greater variations (higher maxima and lower minima) in the former. Sour orange was found, however, to have the smallest vessels in both cases.

(c) In each case, the xylem segments are longer in the species from California than in those from Pretoria. In both cases, the segments of rough lemon are the longest, and of sour orange the shortest, while those of grapefruit are of intermediate length.

4. *Discussion and Conclusions.*

Wiesner (1928) found 8 to 16 xylem vessels per sq. mm. in sour orange, but in the sour orange from Pretoria, and more particularly in those from California, far more xylem vessels were found to occur. According to Wiesner, the diameter of xylem vessels of sour orange is from 40 to 110 μ, but this value is far higher than that found in sour orange from Pretoria or California.

The most important conclusion to be drawn from the comparison is that in Pretoria far fewer vessels occur in sour orange

than in rough lemon or grapefruit, while the sour orange from California has about the same number of vessels as grapefruit and many more than rough lemon. In both cases the vessels of sour orange are much smaller than those of rough lemon or grapefruit. As a consequence, transport of water in the sour orange might be slower than in either rough lemon or grapefruit under normal conditions. Since rough lemon is, and sour orange apparently is not, suitable for use as a stock for grapefruit in South Africa, it is important to know in how far the transport of water is affected by the anatomy. It was therefore decided to determine the relative water conductivity of the three citrus species.

II. Water Conductivity.

1. *Introduction and Literature.*

According to Malhotra (1931), Dixon and Marshall (1915) concluded their investigations that the cross-sectional area of the conducting elements varied for different woods.

In 1918, Farmer determined the relative water conductivity of several varieties of wood, by measuring the amount of water passing through a definite length of stem in a given time and at standard pressure. He found that deciduous trees had a higher water conducting efficiency than evergreens. This difference he found to be the result of the wider and longer xylem vessels of the deciduous trees.

Holmes (1918) studied the anatomy of hazel and ash wood, and concluded that the number of xylem vessels was just as likely to limit the transport of water as the total area of the tracheae. According to Malhotra (1931), she found a lower specific conductivity in ash wood and a higher in hazel wood. There were more vessels in the case of ash wood, but they were smaller than those of hazel wood. According to Malhotra (1931), in the case of ash and hazel wood there is a greater correlation between the water conductivity and the total area of the vessels than between the conductivity and the number of vessels.

Rivett (1920) studied the anatomy of *Rhododendron ponticum* and *Ilex aquifolium* in relation to the water conductivity. He found the length of the xylem vessels to be of greater importance in this connection than the diameter or the number of the vessels.

In 1925 and 1927 Inamdar and Shrivastava investigated the variation in conductivity of deciduous trees in different seasons. They concluded that, in general, the specific conductivity varied with the area of the vessels.

Malhotra (1931) determined the number and area of tracheae and the length of xylem vessels in a large number of fruit trees. He found that—(i) the longest vessels occurred in the longest stems; (ii) there was some correlation between the thickness of the stems and the number of the tracheae; (iii) the

area of the tracheae was of more importance than the number, though the latter sometimes had a considerable effect on the conductivity of the stems.

He concluded from his results that the area, length and number of vessels were not the only factors affecting the conductivity of wood, but that another factor, as yet unknown, might decrease the limiting effect of the area of the tracheae. In 1932 Malhotra concluded from his experiments: "Tendency of regulating conduction stream has been pointed out in these two kinds of tracheae (prune and apple). It seems that larger tracheae may be modified by other factors as viscosity of the sap and the nature of the wall."

2. *Methods and Materials.*

Two methods were used to determine the relative conductivity of rough lemon, grapefruit and sour orange.

(a) The Huber and Schmidt (1936) method.—The relative conductivity was estimated by measuring the amount of water which could be forced through a stem of definite length and thickness at standard pressure in a given time. A number of T-tubes, attached to one another by means of rubber tubing, were connected to a tap at one end and to a long glass tube standing in a 50 cm. column of mercury at the other. To the free ends of the T-tubes stems of equal length and more or less equal thickness were attached by means of rubber tubes. By opening the tap the whole system was filled with water, under a pressure kept constant by the mercury. The water forced through the stems was collected and measured.

(b) The Melhus, Muncie and Ho (1924) method.—The transport of water in the stems was measured by means of a fluometer. The principle on which the method was based was the suction of water through the stems. Water was drawn through each stem for one hour at a suction force of 50 cm. and the relative amounts of water measured.

The stems used for the determination of the relative conductivity were the same as those used for the study of the anatomy. Those from Pretoria were 10 cm. long, bearing leaves, and were cut immediately before use.

3. *Results.*

The results obtained by the Huber and Schmidt method showed considerable variation. Generally speaking, the highest conductivity was found in the case of rough lemon, and the lowest in sour orange (Fig. 5). At first, stems from which the leaves had been removed were used, but water escaped through the leafstalks. Stems with leaves were, therefore, used, and the latter became filled with water. As little is known of the course followed by leaf traces and xylem vessels, it is possible that the number of leaves had some effect on the results. For

this reason the method was discarded and that of Melhus, Muncie and Ho was used.

Fig. 5.—The relative amounts of water transported by Grapefruit (the two stems on the left), Sour Orange (the two stems in the centre), and Rough Lemon (the two stems on the right). After the method of Huber and Schmidt.

The results obtained by the Melhus, Muncie and Ho method are given in the following table, and in graph 1D. For comparison, anatomical details are included in the table.

TABLE II.

	Average thickness of stems in cm.	Transport of water in cc. per hour.	Average number of vessels per sq. mm	Average radial and tangential diameter of vessels in μ.	Length of vessel-segments in μ.
Rough Lemon	·64	14·12	47·6	43·5	207·4
Grapefruit	·60	8·39	47·3	45·3	186·2
Sour Orange	·69	3·15	40·0	34·4	179·9

From this it may be concluded that rough lemon exhibits the highest and sour orange the lowest water conductivity, while that of grapefruit is intermediate. Graph 1D shows the differences in transport. The stems are again numbered 1-10, No. 1 being the stem showing the lowest conductivity in each of the three species, and No. 10 the highest.

III. Comparison of the Anatomy and Water Conductivity.

Comparison of the conductivity and the anatomy of ten stems of each of rough lemon, grapefruit and sour orange revealed no clear relationship between the conductivity and any of the separate factors, namely, the thickness of the stems, the number and diameter of the xylem vessels or the length of the

vessel-segments. The results for the ten rough lemon stems from Pretoria are given in Table III.

TABLE III.

No. of Stem.	Average diameter of xylem vessels in μ.	Area of the xylem sq. mm.	Number of vessels per sq. cm.	Length of vessel-segments in μ.	Transport of water cc. per hour.
A	47·0	·178	46·25	214·0	20·7
B	46·7	·251	58·04	231·6	24·5
C	46·3	·229	41·07	203·7	17·4
D	45·6	·185	57·14	195·3	13·1
E	45·3	·204	54·46	206·9	18·4
F	43·9	·206	49·11	213·4	8·4
G	42·8	·207	41·78	197·8	9·6
H	40·5	·188	33·75	192·4	9·2
I	39·0	·209	41·97	213·8	8·1
J	38·6	·181	50·18	201·8	11·8

From Table III the following conclusion may be drawn. The general trend of the variations in the relative conductivity of rough lemon corresponds to the variations in size of the xylem vessels. The five stems with the larger xylem vessels possessed the highest and those with the smaller vessels the lowest conductivity. There are, however, irregularities, but these can practically all be attributed to other anatomical differences; for instance—

(i) Stem A had the largest xylem vessels but not the highest transport. The transport was probably limited by the small area of wood in this stem and by the smaller number of xylem vessels.

(ii) Stem B exhibited the highest transport although it had not the largest xylem vessels. The stem, however, had the greatest number of vessels and the longest vessel-segments, which may have accounted for the high rate of transport.

(iii) The transport in stem D was low, which is possibly explained by the small area of xylem and the shortness of the vessel-segments.

(iv) The transport in stem F was very low, and this was the only case which could not be explained by the anatomy.

(v) Stem J had the smallest xylem vessels but not the lowest conductivity. This may possibly be explained by the large number of xylem vessels per sq. mm.

It is also possible that there are other contributing factors, as suggested by Malhotra (1931, 1932) and by Inamdar and Shrivastava (1927). In rough lemon, for example, the size of the perforations in the xylem vessels may be of importance. According to Holmes (1918), the length of the xylem vessels limits the transport, but since these stems were 10 cm. in length, this factor was eliminated.

In general, therefore, it can be concluded that in rough lemon the size of the xylem vessels apparently exercises the strongest influence on the transport of rough lemon, although it is also influenced by the total conducting area of the xylem, the number of xylem vessels, and probably also by the length of the vessel segments. These results are in agreement with those of Malhotra (1931).

The results of the grapefruit stems are given in Table IV.

TABLE IV.

No. of Stem	Average diameter of vessels in μ.	Area of the xylem sq. mm.	Number of vessels per sq. mm.	Length of vessel-segments in μ.	Transport of water cc. per hour.
A	52·9	·276	48·5	175·2	14·1
B	50·4	·251	41·9	185·9	9·1
C	49·6	·165	64·5	204·1	10·2
D	46 6	·219	40·4	187·9	10·8
E	45·3	·112	57·9	185·7	9·7
F	43·9	·175	47·2	182·1	9·6
G	43·2	·102	41·3	190·5	5·0
H	41·9	·125	46·4	185·1	7·6
I	39·7	·257	40·7	198·9	3·9
J	38·9	·099	44·3	170·8	3·9

From Table IV the following conclusion may be drawn. As in rough lemon the general trend of the variations in the relative conductivity of grapefruit corresponds to the variations in the size of the xylem vessels. The stems with the smallest vessels exhibited the lowest transport and the stems with the largest vessels the highest transport. There are, however, also irregularities; for instance—

(i) Stems B and C had large vessels, but the transport was low in B and also relatively low in C. This may have been due to the small number of xylem vessels in stem B and the small xylem area in stem C.

(ii) The transport of stem G was low, apparently as a result of the small number of vessels and the small xylem area.

As in the case of rough lemon, therefore, the size of the xylem vessels seems to exercise the strongest influence on the conductivity, but it may also be affected by the conducting area of the xylem, the number of vessels, and perhaps the length of the xylem vessel-segments and other unknown factors.

There is no relationship between the differences in the transport of the ten sour orange stems and the anatomical variations. The transport in sour orange was very low (Table II), and differences in the transport in the various stems were correspondingly small. Similarly, the variations in the size of the vessels and the length of their segments were very slight.

When the figures for rough lemon (Table III) are compared with those of grapefruit (Table IV), the differences in the transport cannot be explained by size of the xylem vessels. The average number of xylem vessels and length of the vessel-segments in grapefruit is smaller than in the case of rough lemon, but the differences are not large enough to account for the differences in conductivity. This suggests that there are other factors not yet studied which determine the differences in conductivity between the various species.

The transport of sour orange is much lower than that of rough lemon or grapefruit. This may be explained by the small xylem vessels, the short vessel-segments and the small number of vessels in the sour orange.

Unfortunately it was impossible to determine the conductivity of the stems from California which were sent in 95 per cent. alcohol. A few experiments with material from Pretoria showed that one week in alcohol increased the conductivity of the stems from 300 to 700 per cent.

IV. Transport of Dyes.

1. *Introduction.*

Dyes were introduced into the stems or roots of citrus trees in order to trace the probable path of water from the roots into the trunk and from the trunk into the lateral branches.

" Yellow-branch " of citrus according to V. d. Merwe and Anderssen (1937) may possibly be due to chromium poisoning. If this is the case it must be assumed that more chromium is taken up by certain roots and that these roots are only, or perhaps mainly, in direct connection with the particular branch or branches in which the symptoms of yellow-branch appear. It therefore seemed of importance to determine whether dye which is introduced either into the trunk at a certain point or into one root would be transported only to a certain part of the tree.

The literature referring to the transport of dyes and other substances in plants has been reviewed by Roach (1938). Several authors, Auchter (1923), Bodenberg (1929), Caldwell (1925 and 1930), Arndt (1929), and others have come to the following conclusions:—

(1) Mineral elements are transported independently of water, and although cross transfer of water in the stem does take place, this does not happen in the case of mineral elements.

(2) Salts or dyes introduced into a root at one side of a tree are transported to a certain part of the tree on the same side as the root.

McMurtrey (1937) was unable to confirm some of the results of the previous authors. Roach (1938) made a thorough study of the course followed by dyes when introduced into fruit trees. He found, for instance, that in the apple trees the movement of the dye was fairly uniform in the youngest annual rings. Dye which was injected into a shallow hole immediately beneath a branch moved into this branch only. If, however, the dye reached the older annual rings, it could also be transported to other branches. If the dye was injected beneath and at a point between two branches, it moved to both branches.

2. *Methods.*

Several methods of introducing dyes and chemical compounds into the plant were used.

(i) The method of injection used by Hector and Loest (1936) was followed. The dye was forced, under pressure, either into a hole bored into a stem or into the stump of a root. The apparatus used has also been described by Roach (1938) and others. It consisted of a modified primus stove from which the burner had been removed.

(ii) A main or secondary root was cut off under water and the stump connected with a reservoir of dye, so that the dye was absorbed by the plant itself.

3. *Experimental Results.*

Experiment 1.

Material: A grapefruit tree in Portuguese East Africa was used. It was budded on a rough lemon stock. The tree was three to four years of age, with a trunk about 4 inches in diameter. Four feet above the ground seven branches had developed.

Methods: Two holes were bored in the main stem at right angles to one another—one 1 foot 9 inches and the other 1 foot below the point at which branching had taken place. The holes were 0·7 inch in depth and in diameter. Methylene blue was forced into the stem under pressure by means of a primus pump. After three hours the tree was cut down for examination.

Results: In the main stem the dye moved upwards directly above the points of injection, but where the branching took place it spread in all directions, entering all seven branches.

It seemed, therefore, that the xylem on one side of the main stem could have been connected with all the seven branches leading in every direction. Attempts were therefore made to trace the course followed by xylem strands from individual roots into the branches.

Experiment 2.

Materials: A 3-4-year-old Valencia orange tree, budded on rough lemon and growing in Rustenburg, Transvaal, was used. The main stem was 3 inches in thickness, and about 3 feet above the ground four big branches had been formed.

Methods: Methylene blue solution was forced under pressure into a root, about ½ inch in diameter, just below the surface of the soil. After 28 hours the tree was cut off 2 feet 6 inches above the ground—that is, 6 inches below the point where branching took place.

Results: As the whole tree was not taken out, the course followed by the xylem vessels from the root to the stem could not be studied. From the main stem the dye spread to the four branches leading in all directions. When the phloem was removed the progress of the dye in the young xylem could also be followed. It spread chiefly to one branch, directly above the injected root. Higher up, this branch divided into three parts, and in all of these the dye was found.

Experiment 3.

Materials: A small rough lemon tree, growing in the grounds of the University, was used. The main stem was about 1 inch in diameter; branching had taken place about 2 inches above the ground.

Methods: A secondary root, near the surface of the soil, and about 0·3 inch in diameter was cut off. The stump was left in a solution of methylene blue for 10 days.

Results: The results are illustrated in Fig. 6A. Though the dye was absorbed by the plant itself, the results were the same as when dye was forced into the stem under pressure. Most dye was found in the main stem just above the root which absorbed the dye. It was also found, however, in the lateral branches, both on the side more or less above the root (branch A) and on the opposite side of the tree (branch B). Branch C, which was apparently closest to the xylem in which transport chiefly took place, contained no dye. Nor was any dye present in a number of the smaller lateral branches leading from the main stem (D, E, and F). Two shoots on branch B contained dye, but no dye was found in a third shoot, G. The dye also moved downwards from the treated root into the main root.

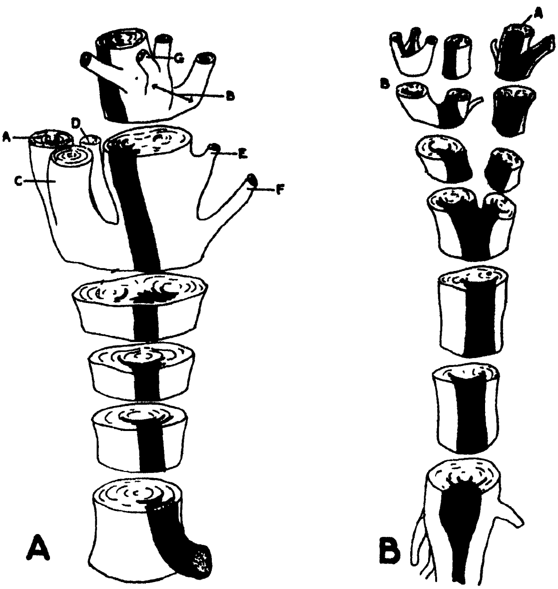


Fig. 6 A.—Transport of methylene blue in citrus stem.
Fig. 6 B.—Transport of chromium in citrus stem.

Experiment 4.

Materials: A young grapefruit tree budded on a rough lemon stock, growing in the grounds of the University, was used. The main stem was 1·5 inches in diameter. Branching had taken place 7 inches above the ground.

Methods: Working upon the suggestion of V. d. Merwe and Anderssen (1937) that chromium poisoning might be the cause of yellow-branch in citrus, a secondary root 0·3 inch in diameter was cut off under water and the stump placed in a flask containing a 2 per cent. chromium alum solution. Root and flask were then covered with soil. After a few months a number of small branches had died back and the tree was removed for examination.

Results: The xylem in which transport of the chromium had taken place was discoloured as a result of the death of the tissues. This xylem could be traced up to various branches. The results are illustrated in Fig. 6B and Fig. 7. Transport had taken place in a number of growth rings. When the phloem was removed, the discoloration in the youngest xylem could be traced leading mainly to branch A. In the case of the other branches, e.g., B, the dead tissues were found chiefly in the older wood and were only visible when the younger xylem was

removed. In Fig. 7 the discoloration inside these branches cannot be seen.

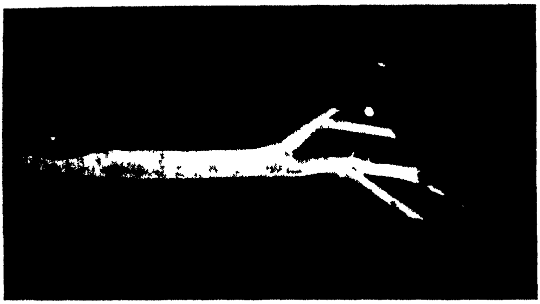


Fig. 7.—Discoloration of xylem caused by chromium taken up by one root.

Experiment 5.

Materials: A grapefruit tree, similar to the one above, was used.

Methods: To establish the relationship between secondary and main roots, a small secondary root was cut off under an eosin solution. The main root was 0·8 inch, and the secondary root 0·3 inch in diameter. After 24 hours the main root was cut up and examined.

Results: Most of the dye in the secondary root was transported to the youngest xylem in the main root, but it also occurred in the older xylem. The longitudinal section of these roots showed that the xylem of the secondary root was directly connected with the older xylem in the main root. It therefore seems improbable that substances absorbed by the smaller secondary roots will only reach the youngest xylem of the stems. From the results of this and the previous experiments it also seems improbable that substances absorbed by one root move either to one branch or even to branches on one side of a tree only.

Experiment 6.

Materials: A branch about 0·5 inch in diameter from a rough lemon tree was used. The two lateral branches A and B in Fig 8 had been cut off close to the base a few months before. As a result of this four new lateral shoots of different sizes, three of which (C. D and E) are visible in Fig. 8, had developed.

Methods: Shoot D formed at the level of the fork between the two original branches was cut off under methyl green solution and a piece of cottonwool soaked in the dye was put on the stump. After 15 minutes the whole branch was removed for examination.

Results: The dye had moved downwards in the xylem of several growth-rings. In the youngest xylem it travelled mainly

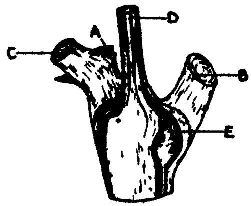


Fig. 8.—Downward transport of dye introduced into shoot D.

in three strands, two of which are shown in Fig. 8. The third strand could be followed up as a narrow green line running across the fork and some distance down at the back of the main branch From this experiment it seems possible that in some cases, depending on the method of branching, the xylem of one branch may be in connection with xylem strands on all sides of the main stem.

4 *General Observations on Anatomy and Transport of Dyes.*

(i) Branching of xylem vessels takes place particularly at nodes where lateral branches are formed. Dye which moves in these vessels may be transported to two different branches.

(ii) Where lateral branches are formed, the xylem vessels may follow a very irregular horizontal or zigzagging course and profuse branching of the vessels takes place.

(iii) The xylem vessels of the youngest xylem are not always in connection with the xylem of the smaller lateral shoots. If transport of dye occurs only in the youngest xylem of the main branches, the dye may be transported round these smaller shoots without entering them (Fig. 8, E). This may happen when the dye is introduced either above or below these shoots. It is possible that the cambium of these shoots ceases division before the cambium in the main branches becomes inactive.

V. Summary.

1. Material of *Citrus limonia* Osbeck (rough lemon), *Citrus aurantium* Linn (sour orange) and *Citrus maxima* Osbeck (grapefruit) for anatomical studies was obtained from trees grown at the University of Pretoria and was compared with material of the same species sent from California.

2. The xylem anatomy of rough lemon is described and details are given of the distribution of xylem elements, number of xylem vessels per sq. mm. and the diameter and length of vessel-segments.

3. All three species from California possessed far more xylem vessels per sq. mm., but the vessels were smaller than those from Pretoria.

4. In the material from California rough lemon had far fewer vessels than either grapefruit or sour orange, while in the material from Pretoria the smallest number of xylem vessels was found in sour orange.

5. In both the material from California and Pretoria, grapefruit and rough lemon had the largest and sour orange much smaller vessels. In both cases also the longest vessel-segments were found in rough lemon and the shortest in sour orange.

6. The water conductivity of all three species from Pretoria was determined. It was found that rough lemon exhibited the highest and sour orange the lowest conductivity. This is in agreement with the difference in anatomy.

7. In rough lemon and grapefruit the size of the xylem vessels seemed to exercise the strongest influence on the conductivity of each individual species.

8. A comparison of rough lemon and grapefruit indicated that the differences in the water conductivity between these two species could not be explained by the size of the xylem vessels or other factors studied. Probably factors such as size of the perforation of the crosswalls, structure of the cellwall, etc., may have a regulating effect.

9. It is possible that the difference in anatomy and water conductivity may influence the compatability of the different species and be of importance in an explanation of the failure of sour orange as a stock in South Africa.

10. Dyes and salts introduced into one root of citrus may be transported to branches on all sides of the tree.

11. Substances transported in the youngest xylem, however, are mainly found on one side of the tree. In this case the substances may travel around some of the branches without entering them.

12. In the older xylem there is a better tangential distribution of dyes than in the younger xylem.

13. Substances transported in the older xylem may enter into all branches. This may be explained by the profuse branching of, and the irregular course followed by the xylem vessels.

14. Should normal transport from root to stem take place only in the youngest xylem, it might be possible that substances absorbed by one root will be transported either to one side of the tree or even to one branch only. As a result of the experiments, however, this seems unlikely.

I am indebted to Dr. M. G. Mes for her assistance and advice, and to the National Research Board for a grant enabling me to carry out the work.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVI, pp. 314-315, December, 1939.*

A FURTHER RECORD OF THE GENUS *ATALAYA* IN SOUTH AFRICA. *A. ALATA* (Sim) H. Forbes

BY

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Read 7 July, 1939.

In this Journal of 1937, Dyer (1) published a paper entitled "*Atalaya capensis*: A New Generic Record for South Africa." The discovery of this genus in South Africa was of very great interest, as it had been recorded previously only from Australia and Timor.

Towards the end of 1936 the Rev. Father J. Gerstner collected a specimen of a small tree at Dukumbane, Hlabisa District, Zululand, which proved to be a species of *Atalaya* In Sim's "Forest Flora of Portuguese East Africa" a description was found of a monotypic genus, *Diacarpa*, the species being *Diacarpa alata* Sim (Sim, 6307). Moreover, it was figured (tab. V.C.). Leaves and fruit only were illustrated as Sim collected no flowering material, but the distinctive shape and dentation of the leaves figured pointed strongly to the conclusion that this plant is the same as Gerstner's specimen, and also a specimen collected by Prof. A. W. Bayer from Ubombo, Zululand. It became clear that the three specimens, *Sim* 6307. *Bayer* 600 and *Gerstner* 2911, all belonged to one and the same species. Sim's specimen consists of leaves and a few mature fruits, Bayer's of leaves only, while Gerstner's has leaves, flowers and one immature fruit. Sim called his plant *Diacarpa alata* on account of the fruit of 2, 1-seeded samaras. In *Atalaya capensis*, although the ovary is three-celled, it is quite usual for one or two carpels to become aborted and even on the one branch fruits with 1, 2 and 3, 1-seeded samaras may be found. The three carpels on the one immature fruit on Gerstner's specimen are equally developed. There can be no doubt that the three specimens mentioned should be placed in the genus *Atalaya*. As the genus *Atalaya* Blume was published in 1847 and Sim did not publish his genus *Diacarpa* until 1909, the latter is here placed in the synonymy of *Atalaya* and the new combination, *Atalaya alata* (Sim), must be made.

Among the Sim material was a specimen labelled "*Diacarpa alata* Sim n. gen. & sp., Lebombos, 1,000 ft., 1908, Sim 21164," and another sheet of the same material with a scrap of paper, "Diacarpa, 21164, type." This material consists of leaves only of *Clausena anisata* (Willd) Hook.f. The only number quoted by

Sim (2) is 6307, and full details as to where the material was collected are written on the envelope containing two 1-seeded samaras. It would appear that Sim must have made a mistake when sorting and writing up his herbarium labels. There is no doubt as to which specimen he described, and the placing of the *Diacarpa* label on the leaves of *Clausena anisata* may be regarded as a clerical error.

Atalaya alata is readily distinguished from *A. capensis* by its leaflets. In *A. capensis* the leaflets are lanceolate, elliptic or oblong-lanceolate and generally entire, while in *A. alata* the leaflets are obliquely oblong-falcate, unequally lobed and toothed along its upper margin.

Atalaya alata (Sim) comb. nov. descript ampl.; *Diacarpa alata Sim* in " Forest Flora of Portuguese East Africa," p. 33 (1908).

A small tree up to 10 m. high, spreading, stem nearly white, warty, and with numerous branches. Leaves paripinnate, 5-7 jugate, petiole slender ending in a short point, 5-15 cm. long, petiole furrowed, sparsely hairy: leaflets alternate or sub-opposite, obliquely oblong-falcate, rounded at the apex, the mid-rib near the lower margin which is entire or with 1 or 2 teeth, upper portion much wider than the lower and toothed along its margin, lower surface a dull paler green than upper, shortly petiolate, glabrescent, 2-7 cm. long, 1-2 cm. wide. *Inflorescence* a terminal panicle; peduncles and pedicels thinly pubescent; bracts pubescent, small, subulate, about 1 mm. long; pedicels 2-4 mm. long. *Sepals* 5, imbricate, suborbicular, two outer ones smaller than three inner ones, concave, ciliate towards base, 1-4 mm. long, 1-3 mm. broad. *Petals* smaller than three inner sepals, shortly stipitate, glabrous on back, with a hairy appendage just above stipe on inner surface, ciliate especially towards base, 3-3·5 mm. long, 1·5-2 mm. broad. *Disc* fleshy, expanded at base and margin notched. *Stamens* 8, inserted within the disc, densely pilose from middle to base; anthers oblong. *Ovary* 3-celled; carpels with 1 ovule, narrowly winged. *Fruit* 1-3 winged; samara up to 3·5 cm. long, 1·4 cm. broad, one-seeded, wing gradually widening, glabrous, distinctly veined.

Distribution.—*Portuguese East Africa*: Maputa Distr., Lebombos, below Estatuene, Sim 6307 (type fruit); *Zululand*: Ubombo, 2,500 feet, July, 1935, Bayer 600 (both in Natal University College Herbarium); Hlabisa Distr. Dukumbane, October, 1936, Gerstner 2911 (type flowers) (Natal Herb., Durban); Ubombo, June, 1939: Gerstner 3473.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVI, pp. 316-327, December, 1939.*

A PRELIMINARY REPORT ON THE COMPARATIVE AGES OF SOME IMPORTANT EAST AFRICAN TREES IN RELATION TO THEIR HABITATS

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With 1 Text Figure.

Read 7 July, 1939.

A.—INTRODUCTION.

The work described in this paper was carried out at Kakoma, a research station of the Tsetse Department of Tanganyika Territory. Kakoma is 65 miles south of Tabora in the Western Province; its altitude is 3,606 feet. The country is very flat, the nearest hills being about 25 miles away, and the average annual rainfall is between 35 and 40 inches. Jackson (1936) showed that the highest average maximum temperature for the year 1936 was in November, and was 92·2°F. and the lowest average minimum was in July, i.e., 50·7°F. There is a marked wet and dry season, the duration of the wet season being approximately from October to May. As the country is so flat, outcrops are rare, but the underlying rock is shown on the geological map to be that of the Lower Basement Complex. The soils vary greatly with locality, and range from yellow, sandy loam to heavy, black clay, and most of them are probably very acidic. The time at which the observations in this paper were made was between July and October, 1938.

Local Terminology.

Mbuga = flat, open country, usually a slight depression; often waterlogged for several months of the year; in South Africa the term would be *Vlei* country.

Miombo = Kiswahili term applied to most types of *Brachystegia-Isoberlinia* woodland.

Ilula = Kiswahili term for all species of Gall-*Acacia*.

B.—ECOLOGY.

An attempt has been made to study the plant communities at Kakoma from a broadly ecological aspect, and to arrive at some idea of the relative positions of these communities, with relation to one another.

It has been decided that the successional scale of the Kakoma plant communities might approach something similar to this.

7. Riverine Vegetation, Thicket Vegetation and Termite-Hills.	Climax.
6. Miombo	Sub-climax.
5. Mixed miombo, with *Combretum* and *Terminalia* and with or without occasional termite hills and *Afrormosia*.	Semi-Mbuga.
4. *Acacia Rovumae*, *Combretum* spp.. *Afrormosia*, *Terminalia* and termite-hills and with or without other *Acacia* spp., and *Lannea*.	
3. *Combretum* spp., *Acacia* spp. sometimes *Lannea humilis*, and *Terminalia torulosa*.	
2. Semi-hydrosere, with *Acacia* sp. in more or less isolated communities.	Mbuga.
1. Hydrosere, permanent water-holes, with rushes, sedges and hygrophilous grasses.	

1. *Hydrosere.*

This consists of more or less permanent waterholes usually found in mbugas, fringed by a ring of tall grasses and sedges, and sometimes by rushes. Often but not always several *Borassus* palms may be found in the neighbourhood.

2. *Semi-Hydrosere.*

Acacia sp., ilula, in more or less isolated communities. This type commonly consists of *Acacia* sp. nov. in isolated communities. Though these *Acacia* communities often merge into type 3 and 4, in type 2 they usually grow on sites such as the middle of an mbuga, where the water takes longest to dry up. Communities of *Lannea humilis* are sometimes found in similar sites to. or associated with, this *Acacia* type. The commonest grasses found in this type are *Loudetia superba* De Not., *Andropogon* sp. and several others.

3. *Combretum* spp. and *Acacia* sp. sometimes *Lannea humilis* and *Terminalia torulosa*.

This is the most representative mbuga type, but appears to be less hygrophilous than type 2, as it is most often found nearer the edges of the mbuga, where the water would dry up more quickly than in type 2. In some cases, however, where the mbuga is " shallow," type 2 is not represented, and type 3 may cover the whole mbuga. Species most representative of type 3 are: *Combretum ternifolium* Engl. & Diels, *C. grandifolium* F. Hoffm., *C. Fischeri* Engl., *Acacia* sp., ilula.

Combretum ternifolium may be considered the important species in this type. The grasses represented here are similar to those in type 2.

4. *Acacia Rovumae*, *Combretum* spp., *Afrormosia*, *Terminalia* and termite-hills and with or without other *Acacia* spp. and *Lannea*.

Type 4 may be considered an extreme phase of type 5. It is usually found on the edges of mbugas, and is probably on ground that is under water for a certain period during the year, but not for as long as that in any of the preceding types. The grasses, as far as could be determined, are similar to those in types 2 and 3. Types 3 and 4 are often characterised by a frequent and very even occurrence of large termite-hills, on the tops of which a thicket type of vegetation is almost invariably found (see type 7). *Afrormosia angolensis* is associated with termite-hills in almost every case, but as *Afrormosia* generally grows between the hills and not on them, it is felt that its true place is between types 3 and 4, and that although it is undoubtedly associated with termite-hills it cannot be classed with the thicket found on them.

The commonest species belonging to type 4 are: *Acacia hebecladoides* Harms, *A. Rovumae* Oliv., *Afrormosia angolensis* Harms, *Combretum apiculatum* Sond., *C. Fischeri* Engl., *C. grandifolium* F. Hoffm., *C. ternifolium* Engl. & Diels, *C. Zeyheri* Sond., *Gardenia* spp., *Lannea humilis* Oliv., *Terminalia sericea* Burch., *T. torulosa* F. Hoffm.

5 *Mixed Miombo*, with *Combretum* and *Terminalia* and with or without occasional termite-hills and *Afrormosia*.

Mixed miombo seems to inherit qualities both from the miombo type and type 4, but differs from type 4 in that it is intermixed with *Brachystegia* and *Isoberlinia* species, as well as several other miombo constituents. The commonest grasses in this type are similar to those of the Miombo type (to be described under Miombo, and Secondary succession). The following is a list of typical plants found in type 5: *Acacia Rovumae* Oliv., *Afrormosia angolensis* Harms, *Brachystegia Boehmii* Taub., *B. longifolia* Benth., *B. spicaeformis* Benth., *B. Wangermeana* de Willd., *Burkea africana* Hook., *Combretum apiculatum* Sond., *C. grandifolium* F. Hoffm., *C. Fischeri* Engl., *C. Zeyheri* Sond., *C. ternifolium* Engl. & Diels, *Erythrophloeum* sp., *Isoberlinia globiflora* Hutch., *I. tomentosa* Hutch., *Phyllanthus discoideus* Mull., *P. Engleri* Pax, *Pterocarpus angolensis* D.C., *Terminalia sericea* Burch.

6. *Miombo.*

This is the most extensive of all the vegetation types around Kakoma, and is characterised by the dominance of several species of *Brachystegia*. A large number of other genera are also represented, and quite a number of species belonging to thicket and riverine types occur.

As most of the miombo has been under native cultivation at some period, it is very difficult to tell what the original type grasses are, but from what was observed of the relic communities of these type grasses, it might be surmised that they were some of the following:—*Andropogon* spp., *Anthephora* sp., *Microchloa indica* Beauv., *Panicum* spp., *Sporobolus* spp., *Trachypogon plumosus* Nees ?

A large number of other species are represented, but these will be discussed under secondary succession.

The most typical tree species found in the Miombo are: *Albizzia* several spp., *Brachystegia Boehmii* Taub., *B. longifolia* Benth., *B. spicaeformis* Benth., *B. Wangermeana* de Willd., *Burkea africana* Hook., *Canthium* several spp., *Cassipourea mollis* Alston, *Chrysophyllum argyrophyllum* Hiern., *Combretum apiculatum* Sond., *C. Fischeri* Engl., *Crossopteryx febrifuga* (Afzl) Benth., *Dalbergia* several spp., *Dichrostachys glomerata* (Forsk.) Hutch. & Dalz., *Diplorrhynchus mossambicensis* Benth., *Erythrophloeum* sp., *Ficus* spp., *Heeria insignis* O.Ktze., *Hymenocardia mollis* Pax, *Isoberlinia globiflora* Hutch., *Kigelia aethiopica* Engl., *Lonchocarpus capassa* Rolfe., *L. eriocalyx* Harms. *Markhamia obtusifolia* Sprague, *Mundulea sericea* Benth., *Paivaeusa dactylophylla* Welw., *Phyllanthus discoideus* Mull., *P. Engleri* Pax, *Popowia obovata* Engl. & Diels, *Pseudolachnostylis maprouneaefolia* Pax, *Pterocarpus angolensis* D.C., *P. chrysothrix* Taub., *Randia kuhniana* Hoffm. & Schum., *Schrebera koiloneura* Gilg., *Sclerocarya birrea* Hochst., *Strychnos* several spp., *Vitex* several spp.

7. *Riverine Vegetation, Thicket Vegetation and Termite-Hills.*

Riverine vegetation has been classed with vegetation on termite-hills, for the reason that large termite-hills frequently occur along the banks of the rivers near Kakoma, and the vegetation on termite-hills in mbuga sites is similar to the vegetation on the river banks.

A large number of the plants in this type are thicket-forming plants such as creepers, shrubby bushes and trees, e.g., *Zizyphus mucronata* Willd., *Diospyros mespiliformis* Hochst., and *Mimusops densiflora* Engl.

Some of the commoner plants found here are: *Acacia pennata* Willd., *Albizzia* several spp., *Bauhinia Thonningii* Schum. *Bridelia* spp., *Canthium* spp., *Chrysophyllum argyrophyllum* Hiern., *Combretum obovatum* F. Hoffm., *Cordia* sp., *Commiphora* sp., *Dalbergia* spp., *Dichrostachys glomerata* (Forsk.) Hutch & Dalz., *Diospyros mespiliformis* Hochst., *Ehretia coerulea* Gürke., *Fagara Merkeri* Engl., *Ficus* spp., *Flacourtia Ramontchi* L'Herit., *Garcinia Livingstonei* T. and *Gardenia* spp., *Grewia several* spp., *Gymnosporia nemorosa* Szyszyl., *Harrisonia abyssinica* Oliv., *Heeria insignis* O.Ktze., *Markhamia obtusifolia* Sprague, *Mimosa asperata* L., *Ochna* sp., *Phyllanthus discoideus* Mull., *Popowia obovata* Engl. & Diels, *Pseudolachnostylis*

maprounaefolia Pax, *Randia kuhniana* Hoffm. & Schum., *Schrebera koiloneura* Gilg., *Syzygium guineense* (Willd.) D.C., *Strychnos heterodoxa* Gilg., *Tamarindus indica* L., *Teclea glomerata* Verdoorn, *Vitex* several spp., *Vangueriopsis lanciflora* (Good) Robyns, *Ximenia caffra* Sond., *Xylopia Antunesii* Engl. & Diels, *Zizyphus jujuba* Lam., *Zizyphus mucronata* Willd.

The commonest grasses found in this kind of vegetation, as far as it was possible to ascertain, were: *Andropogon* spp., *Aristida* spp., *Brachiaria* spp., *Cynodon dactylon* Pers., *Cymbopogon excavatus* Stapf., *Digitaria* sp., *Eragrostis* spp., *Hyparrhernia* sp., *Panicum maximum* Jacq., *Setaria* spp., *Themeda triandra* Forsk., *Loudetia superba* De Not.

Discussion on Climax.

To the writer the true climax vegetation for the country around Kakoma is represented by termite-hills and riverine vegetation, which consists essentially of a thicket type in which certain tall trees such as *Mimusops* and *Diospyros* are represented.

It would appear that termite-hills act as " strongholds " for the climax type of vegetation. The reasons for this statement are:

1. Vegetation on termite-hills is seldom severely burnt by grass fires.

2. The termite-hills act as a natural protection against native cultivation and the vegetation is not cut out, as there is a great reserve of more easily obtainable wood in the miombo type.

3. The soil on these termite-hills is undoubtedly more fertile than the surrounding soil, as it is sure to contain a large amount of decaying termite matter which would raise its humus and nitrogen content.

A proof of this higher fertility may be shown in the fact that the termites " cultivate fungus gardens " inside these hills. The fungus is most probably saprophytic and would therefore subsist on termite refuse and dead plant matter, such as decaying leaves, which have fallen into the termite " shafts," or dead plant roots.

4. The termite-hills are usually fairly large, i.e., up to 12 feet high, and proportionally wide, so that during the wet season most of the plant roots would be well above the level of the water covering the surrounding country; thus these hills would afford a less extreme habitat than would be afforded by the country around, which is under water for part of the year.

5. Termite-hills form a stable habitat, as has been proved by the fact that large trees growing on them are usually found to be of extreme age e.g., *Zizyphus mucronata* growing on tops of termite-hill 12 feet high was found to be 90 feet high, 36 inches in diameter at base, and exhibited 163 annual growth rings.

Mimusops densiflora on a smaller termite-hill was 60 feet high, 20 inches in diameter, and showed 174 annual growth rings.

It would seem that the termite-hill type of vegetation is the potential climax vegetation for all the country around Kakoma, and the reasons for this statement are:—

1. It is doubtful whether any of the miombo trees are as much as 200 years old, since these trees are periodically cut out by the natives to clear the ground for cultivation.

2. Most of the grasses found in the miombo belong to the type that come in after the ground has been disturbed e.g., by cultivation.

3. Veld fires sweeping through the miombo annually would burn out most of the young thicket-forming climax trees, unless they could recede to the protection of termite-hills, as there are no other forms of protection such as rocks or hills.

While discussing the subject of termite-hills, Dr. Jackson pointed out a most interesting phenomenon connected with them. This was the fact that all the large hills described above had cores of white nodular calcareous material. Often great deposits of this calcareous material exist. Three holes dug through different mounds to a depth of 10 feet below the surface were not deep enough to pass through the calcareous zone. What is the origin of the line? Is it derived directly from the soil by the termites, or is it a faecal deposit derived from digested wood? The latter theory seems the more likely as the underlying rock seems to be schist of the Basement Complex, which is unlikely to be rich in lime, and there are no local deposits of lime apart from those described above; also the soil is very siliceous and is therefore probably very acid.

It this lime is derived from digested plant matter, then the termite hills must be of extreme age, as in most cases the extent of the deposits can be measured in tons. Assuming that the soil is poor in calcium, the local plants themselves would not be over-rich in calcium, and it is easy to imagine that it must take an extremely long time to build up such large deposits.

Another point of interest is that these lime concentrations seem to be confined to the very large mounds only, and do not occur in the smaller tremite-mounds which are frequent in the miombo. The presence of lime in these large mounds would naturally be of great importance in the fertility of their soil (see "Discussion on Climax," above).

Milne (1936), in his "Report on a Soil Reconnaissance Journey," says:

> "No account of the soils of Unyanyembe would be complete without mention of the large termite-mounds, of the shape of a cocked hat and of diameter up to 10 metres at the base, which are dotted about everywhere at the rate of about two to the acre. They are remarkable in a region of non-calcareous soils, by their large content of Calcium Carbonate. A test with the acid bottle usually gives effervescence at the surface of the heap. In section, as exposed when the road happens to cut through the middle of

one, the earth composing the mound becomes more calcareous towards the centre, with visible carbonate nodules, and the core and the base of the heap below ground level consists of a hard concretionary mass of impure limestone. How deep this last formation goes I do not know."

As to the origin of the calcium, Milne writes:

"To have become concentrated in this manner it must either have been drawn from the ground waters as bicarbonate by a purely physical capillary mechanism due to the structure of the heap, or have been gathered by the termite itself over a wide area from the soil in which it feeds. In a region of alkaline ground waters and of soils in which a horizon of carbonate accumulation occurred as a standard morphological feature, it would be reasonable to accept the purely physical explanation.

"Whilst bearing the purely physical explanation in mind as a possibility to be re-examined when the conditions of soil formation as a whole in the area are better known, it is worth looking at the alternative biological explanation. I do not know whether it is admissible on the known facts of termite habits and metabolism, and the literature available gives little help. It would require that this species of termite, whatever it is, builds up the lime-carbonate accumulations not from free $CaCO_3$ present in the soil, for of that there is none, but from lime present (a) as a mineral ingredient of plant remains, or (b) as a part of the soil substance itself, the exchangeable lime of the clay-humus complex. A possible but not very probable source is that lime ingested incidentally with the insect's food is excreted mainly in the heap. A second possibility is that the breeding stages, conducted within the heap, require an alkaline environment (perhaps for the propagation of a necessary fungus), in which case the gathering of lime would not be incidental but purposeful. A third and simpler possibility is that organic residues are carried into the interior of the heap, for nursery purposes, from a considerable distance around, their energy and nitrogen content being there utilised, and the mineral residues left to accumulate over long periods of time. The fact that even the outside of the heap is calcareous suggests also that the earth composing the heap has been cemented together for structural strength by a calcareous secretion, the necessary lime for this 'mortar' having been derived from the mineral constituents of soil humus or plant tissue consumed as food. The concretionary habit of the accumulations in the middle of old heaps is probably an effect of repeated wet season-dry season moisture changes and local capillary movements."

Secondary Succession.

Secondary succession is the type of plant succession which takes place as a result of some external disturbance such as cultivation by man or overgrazing by animals, or several similar influences combined. At Kakoma the chief cause of secondary succession is the cutting out of miombo trees, and the cultivation of this ground by natives. On account of the soil soon becoming exhausted by cultivation, the natives move from place to place periodically. Mbugas are also cultivated to some extent, but as they are under water for a good part of the year, they do not show as definite a reaction to this type of disturbance as does the miombo country. However, one definite indication of disturbance in mbugas is the abundant occurrence of *Hyparrhenia* spp. (the tall grass usually used by natives for thatching).

Hyparrhenia also occurs after such disturbances as overgrazing and tramping by game. Hence the fact that there is often a ring of *Hyparrhenia* around waterholes. In the miombo, signs of disturbance are often clearly marked for as long as 50 years after the disturbance.

As soon as a piece of cultivated country is abandoned, regeneration of the miombo trees takes place, and different grasses appear from those found in undisturbed miombo country. A predominance of certain genera or species of the trees may occur. Naturally, it takes a number of years for the trees to grow up, and in order to get some idea of the comparative ages of miombo trees a few were cut down, their girths were measured, and their annual growth rings were counted, e.g.:

1. *Pterocarpus angolensis*: Height, 40 feet; diam., 10 inches; rings, 21.
2. *Isoberlinia globiflora*: Height, 12 feet; diam., 2½ inches; rings, 12.
3. *Mymenocardia mollis*: Height, 8 feet; diam., 1¾ inches; rings, 12.
4. *Brachystegia Boehmii*: Height, 20 feet; diam., 3½ inches; rings, 18.
5. *Brachystegia Boehmii*. Height, 30 feet; diam., 5½ inches; rings, 23.
6. *Brachystegia spicaeformis*: Height, 25 feet; diam., 5 inches; rings, 22.
7. *Brachystegia spicaeformis*: Height, 30 feet; diam., 6¼ inches; rings, 24.
8. *Strychnos pungens*: Height, 15 feet; diam., 3½ inches; rings, 15.
9. *Kigelia aethiopica*: Height, 40 feet; diam., 20 inches; rings, 50.
10. *Terminalia sericea*: Height, 25 feet; diam., 7½ inches; rings, 18.
11. *Pterocarpus angolensis*: Height, ±50 feet; diam., 25 inches; rings, 150.
12. *Isoberlinia globiflora*: Height, ±50 feet; diam., 15 inches; rings, 132.
13. *Isoberlinia globiflora*: Height, ±50 feet; diam., 13½-14½ inches; rings, 120.

From the above data it can be seen that even *Kigelia*, with a diameter of 20 inches, does not exhibit more than 50 rings, whereas *Mimusops densiflora*, with a diameter of 20 inches, has 174 rings. From this it would seem that a large number of the Miombo trees are quick growers as compared with trees of the undisturbed Primary Successional types, and therefore it might be correct to assume that Secondary Successional changes take place after some sudden external disturbance as compared with Primary Successional changes, which seem to be so slow that

they could almost be measured in terms of geological time, e.g., age of *Mimusops* and *Zizyphus* (see below).

Further Examples.

Afrormosia angolensis: Height, 60 feet; diam., 16½ inches; rings, 180.

Afrormosia: Height, 40 feet; diam., 8½ inches; rings, 90.

When it is considered that *Mimusops* and *Zizyphus* were growing on top of termite-hills, it is easily conceivable that these termite-hills must be at least 50 years older than the trees on them. This means that as previously remarked, changes due to natural causes must take place infinitely slowly, as compared with Secondary Successional changes, and that in the case of Primary Succession, the limiting factors are soil water, soil texture and fertility—apart from the controlling external climatic influence, which is common to all types.

Trees suggestive of secondary succession in Miombo are:

Strychmos Burtoni Bak.
S. pungens Sol.
S. spinosa Lam.
S. schumanniana Gilg.

These normally occur in Miombo, and are often more abundantly present on disturbed sites. This was also noticed by Mr. Kirk at Kakoma.)

Brachystegia spicaeformis and *Isoberlinia globiflora* seem to occur more abundantly on disturbed sites than elewhere, and *Hymenocardia mollis* appears to be an indicator of disturbance to some extent. Grasses commonly found on disturbed sites (e.g., cultivated land) are: *Aristida* several spp., *Brachiaria* spp., *Chloris pycnothrix* Trin., *C. virgata* Stapf, *Cymbopogon excavatus* Stapf, *Cynodon dactylon* Pers., *Digitria* spp., *Eragrostis* several spp., *Hyparrhenia* spp., *Perotis indica* K.Schm., *Pogonarthria falcata* Rendle, *Rhynchelytrum roseum* Stapf, *Setaria* spp., *Sporobolus* sp., *Tragus racemosus* All., *Urochloa* spp.

On account of the writer being unfamiliar with the grasses at Kakoma, it was found difficult to make estimates as to the frequency of their occurrence as they were all in a very dry condition and were difficult to identify. Grasses have been found to be excellent ecological indicators, and often where other methods are uncertain, a knowledge of the ecological habits of grasses makes it possible to reconstruct the history of an area with some degree of accuracy.

A Suggestion for the Estimation of the Comparative Ages of Dominant Trees in Different Ecological Communities.

From the information obtained by cutting trees of different sizes in different ecological sites, it appears that a formula or a graph for estimating the comparative ages of trees by measuring their girth, might be worked out quite easily by cutting several trees down and plotting their girth measurements against their

numbers of rings. In this way a graph for separate species would be made, from which the approximate number of rings in any tree of that species can be worked out by the previous knowledge of its girth.

After further investigation of this subject it was found that apparently most miombo trees make wide rings for the first 25 years of their growth, but as they get older they grow much more slowly, and make much narrower rings, so that the relative ages of young trees and old trees with relation to girth are not comparable. For example, an *Isoberlinia globiflora* 2½ inches in diameter showed 12 rings, but another tree 15 inches in diameter had 132 rings. According to simple proportion, the second tree of 15 inches should have $\frac{12 \times 15}{2\frac{1}{2}} = 70{\cdot}2$ rings, which is obviously wrong.

Yet in the case of another two trees with diameters approximately the same, the proportion works out almost exactly, e.g.:

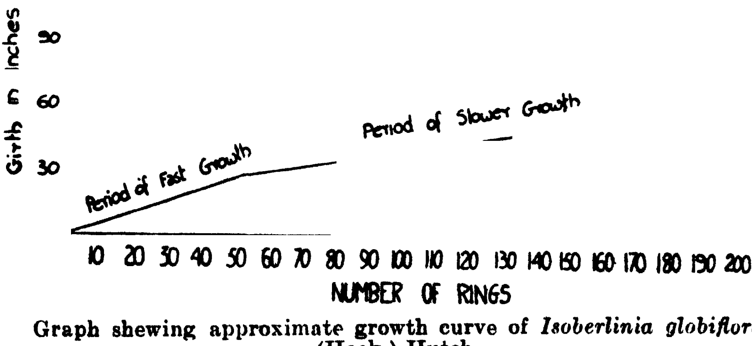
A: Diam. 15 inches had 132 rings.

B: Diam. 14 inches had 120 rings.

By proportion, $\frac{132 \times 14}{15} = 121$ rings.

Circumference = Diam. x 3·14.

From the above evidence it would seem that the simple proportion method would hardly be practical unless used for trees of approximately the same diameter, but if large numbers of trees were used it would be possible to work out a graph from which could be plotted the ages of both young and old trees of the same species, as the graph would record the difference in growth rate between young and old trees, e.g., the growth curve for *Isoberlinia globiflora* would be steep for approximately the first 50 years and would then flatten out quite considerably (see graph).



Graph shewing approximate growth curve of *Isoberlinia globiflora* (Hook.) Hutch.

The accompanying graph was worked out from data obtained by counting the growth rings and measuring the diameters of a number of trees of varying ages of *Isoberlinia globiflora.*

Conclusion.

1. It is conceivable that by cutting trees of varying ages down, it would be possible to work out formulae on the lines described above, for finding out the approximate ages of trees by measuring their girth, but separate formulae would have to be worked out for different species.

2. The quick estimation of the approximate ages of trees, and hence blocks of bush, would be invaluable as an aid to finding out the past history of their habitats and thus facilitating the task of working out their relative successional positions.

3. From the data procured at Kakoma, where several very large trees were cut down, it seems unlikely that miombo trees grow to an age very much exceeding 200 years, as most of the large trees had heart-rot, and none of the trees cut down had more than 200 annual growth rings, while quite a number of them were hollow and decayed inside, when they showed no outward sign of this.

Summary.

1. *Introduction*, giving a general description of the locality discussed.

2. *Ecology* The following successional types are described: (a) Mbuga, (b) Semi-mbuga, (c) Sub-climax, (d) Climax.

3. *Secondary Succession.* In which the causes of Secondary Succession are discussed, and the ages of a number of trees which were cut down are given, according to the numbers of their annual growth rings.

4. A possible method of finding the ages of trees by measuring their girth is discussed.

5. *Conclusion.*

6. *Summary.*

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AN IMPROVED METHOD OF SOWING GRASS AND KARROO SHRUB SEED

BY

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With 8 Text Figures.

Read 7 July, 1939.

INTRODUCTION.

A good deal of attention has been paid to the propagation of Karroo shrubs under nursery conditions, but little work of a practical nature has been done with regard to the re-seeding of bare veld. It has generally been looked upon as quite impracticable for, in the few cases where such sowing was undertaken, the germination of seed was poor and the undertaking was not economically sound. The chief reasons for the failures in veld sowing, on average browsed Karroo veld, can be summarised as follows —

(1) The seeds, when lying exposed on the veld, are apt to be carried away by birds and insects, particularly ants

(2) Usually seed sown on slopes or undulating surfaces is washed away during rains or blown away by the wind in dry weather.

(3) Even should the exposed seed lie undisturbed—especially in the case of large seeds, it has only a small chance of germinating owing to want of soil cover. In most cases, it is only when such seeds are covered by wind-borne sand that they germinate.

(4) Many of the Karroo shrubs have seeds with pappus or other projections. Such seeds cling together in a mass and are very difficult to sow broadcast.

After repeated attempts and many failures with re-seeding on the Gebroke Karroo veld of the Worcester Veld Reserve, the writer tried various methods of treatment of seeds before sowing. The results of a cheap and simple method have been so amazing that it is being presented here.

METHOD.

The method consists merely of coating the seeds with mud. Various mixtures were tried out, such as mud alone, mud and

manure, and finally mud, manure and flour size. After much experimentation, it was found that flour size was absolutely essential, and that the best proportions were 8 parts sifted clay loam, 1¼ parts sifted old stable manure, one-fifth part low-grade flour, prepared into size, ½ to 2 parts of seed (depending on the size of the seed).

The flour size is made by taking the required quantity of flour and adding sufficient cold water to it to enable the whole to be worked into a thin paste. This paste is then poured slowly into boiling water and the mixture kept well stirred and allowed to boil for 2 or 3 minutes. Sufficient cold water is then added to the mixture to bring it up to the required amount of size necessary.

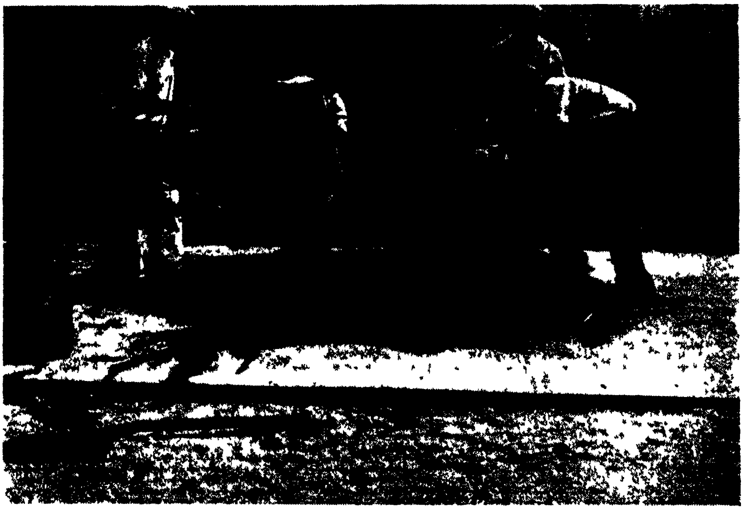

Fig. 1.—Shows correct method of mixing ingredients.

The mixing is done on a cement floor or any smooth, hard surface. The clay loam, manure and seed are first thoroughly mixed, and then the size is added by means of a watering-can with a rose. The mixture is well worked until it is thoroughly saturated. It is necessary to add the size by means of a can with a rose for, if large quantities of size be added at a time, the seed is apt to float and thus become badly distributed (see Fig. 1).

The mixture is worked to the consistency of plaster mortar when it is spread out to a thickness of ¼in. to ½in., depending on the size of seed. This is conveniently done by using the back of an ordinary garden rake. When this operation has been completed, the mixture is raked crosswise with the right side of the rake, so as to work the whole mass into small particles

containing seed (see Fig. 2). It is often found necessary to spray the portion being raked so as to facilitate the working of the rake and to prevent large lumps being formed.

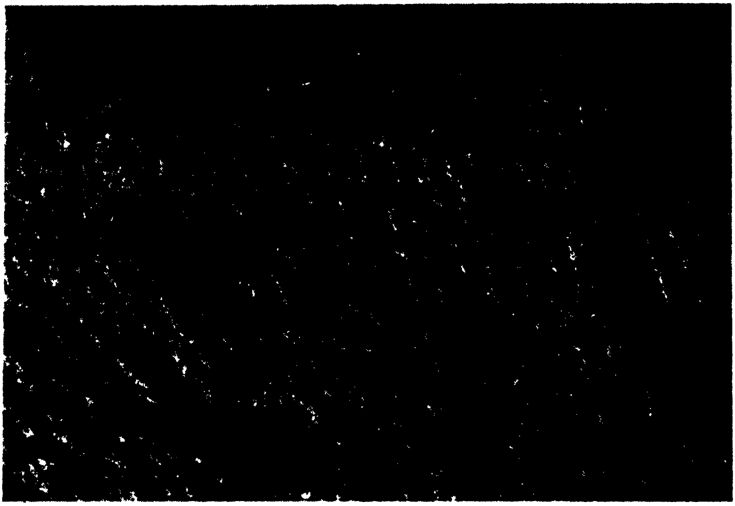

Fig. 2.—The mixture raked out ready for drying.

When the mixture is thoroughly dry, which takes from three to four hours in dry weather, a sharp spade is taken and, by a forward movement, with the spade hard against the ground surface, the mixture is loosened and separates into clay particles containing the seed (see Fig. 3). These are now ready for sowing,

Fig. 3.—The mixture being loosened and broken up into particles.

though it may be necessary to break up a few of the larger pieces.

A mixture containing 16 buckets of clay loam, 9 lbs. of flour made into 32 gallons of size, 3 buckets of fine manure, and 2 buckets seed of *Atriplex nummularia* was sufficient to sow 2½ morgen of veld with the clay particles scattered approximately 12 inches apart. The total cost of ingredients and labour amounted to 2s. 6d. (excluding cost of seed).

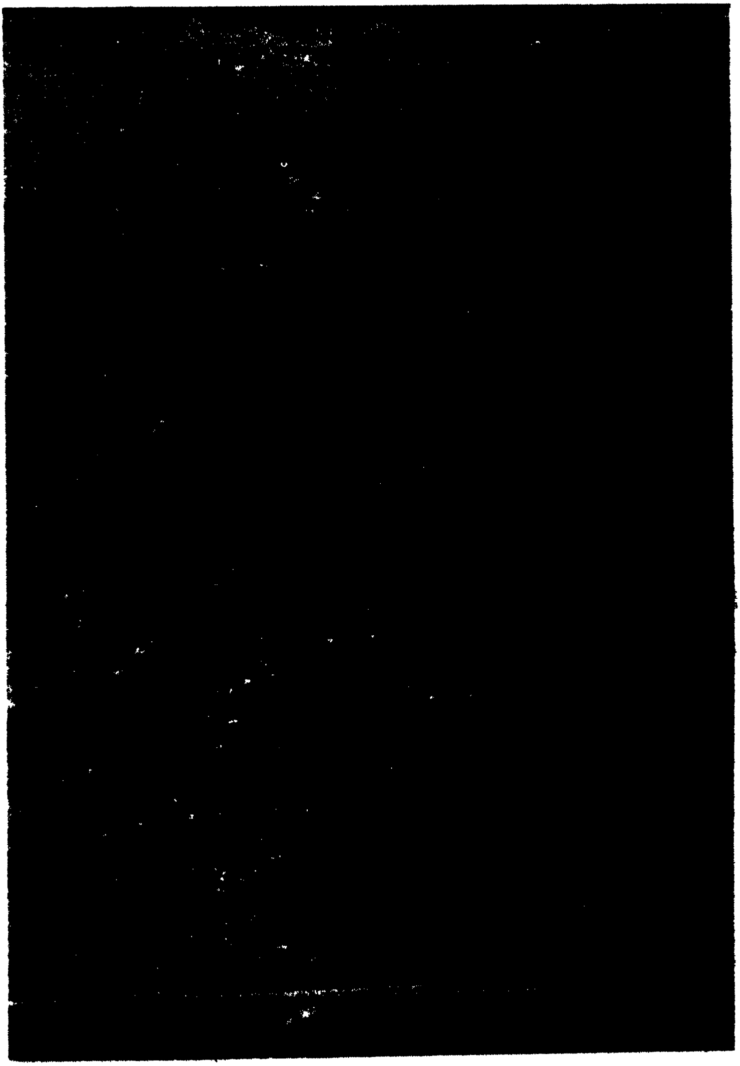

Fig. 4.—Shows mud-coated seeds sown and anchored on slope and how the seed is protected from being carried away by ants.

Discussion.

Although this method of mudbathing of seed has so far been tested only in the Winter Rainfall area, it is anticipated that it will be equally successful in the Summer Rainfall areas. The

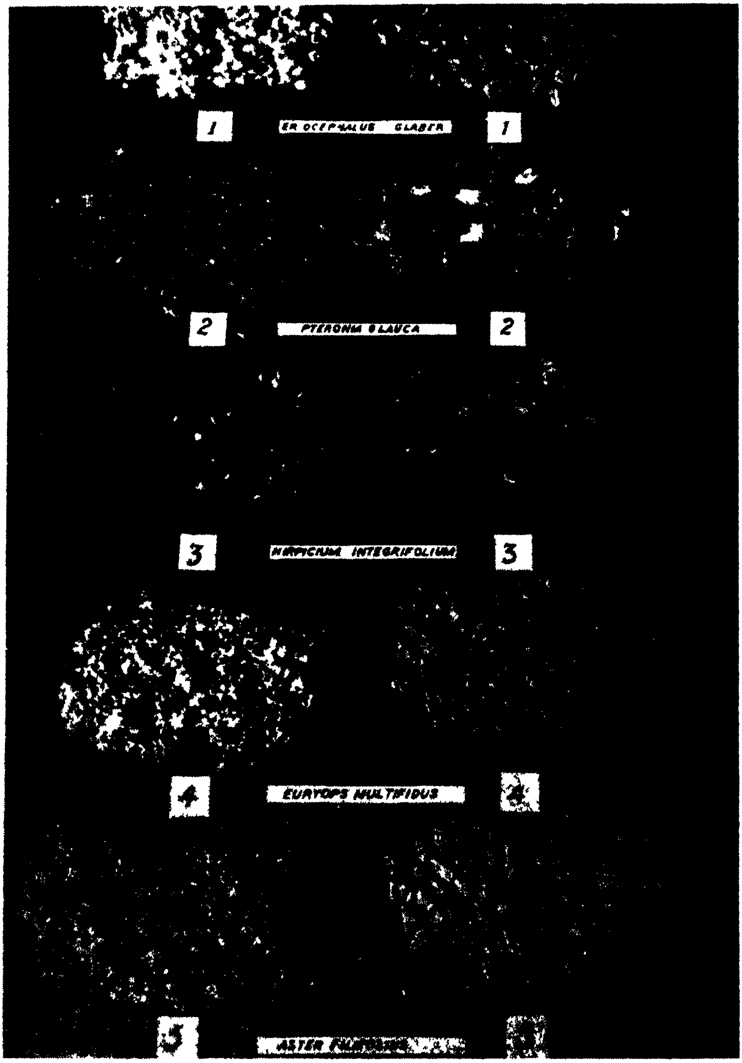

Fig. 5.—Seeds which are are pappiferous can be easily broadcasted when mud-coated.

Left: Showing clean seed.

Right: Showing seed of same species after having been mud-coated.

results with both Karroo shrub and grass seeds in the open veld have been astonishingly good.

The flour size is an essential ingredient in the mixture because it helps to bind the soil, and thus prevents the mud-coat from being washed off the seed during heavy rains. When a solid piece of the mixture of flour size and soil was immersed in water, it showed no signs of disintegration after 17 hours, while a piece of clay loam alone, of the same dimensions, disintegrated within ten minutes.

The advantages gained in mudbathing the seed are many, and can be summarised as follows:—

(1) Anchorage. After the first good rains, the clay particle containing the seed becomes attached to the soil surface, and thus the seed can be sown on steep slopes without fear of its being washed away (see Fig. 4).

(2) As the seed is coated and anchored, it is protected from being carried away by wind, water, birds or insects (see Fig. 4).

(3) At the base of the particle, after it has been attached to the soil surface during rain, there is retention of moisture which encourages the seedling to penetrate the soil.

(4) Seeds which are pappiferous and inclined to mat are kept separated and thus are easily broadcast (see Fig. 5).

(5) Mud-coated seed can be distributed very evenly, and thus, when broadcast, there is great economy of seed (see Figs. 6 and 7).

Fig. 6.—Broadcasting Prepared Seed.

Fig. 7.—Right heap shows clean seed of *Pentzia incana*.
Left heap shows same quantity of Pentzia seed mud-coated.

(6) Any material used for stimulating the germination of the seed can easily be mixed with the mud. (The writer has found that, where 1 per cent. HCl is used instead of water for making up the mixture, there has been definite stimulation of germination, especially in the case of seeds with after ripening periods.)

(7) The method is cheap, practical and successful (see Fig. 8).

The writer would like to add that encouraging results have been obtained in using the described mud-coating method in the propagation of stoloniferous grasses, by cutting off the nodes from the stolons and mud-coating these by the same method described for seed. The prepared soil particles containing the nodes can be broadcasted as in the case of seed. Should it be necessary to wait for favourable weather conditions after having prepared the nodes for broadcasting, then the nodes can be prevented from dying by keeping the entire mixture slightly damp by fine, light spraying of water at different intervals.

The addition of "Hormones" in the mixture for stimulating root production of the nodes is being tested, and encouraging results are being obtained.

The idea of mud-coating seed was given the writer by one of our Karoo plants *Euryops multifidus*. He noticed that the seed of this plant germinates very well on bare and uncultivated ground, and on investigation found that the chief reason for this was, that the seed, after the first rain, throws out a sticky jelly, which in a remarkably short time collects dust and forms an earth coat around the seed. The jelly not only collects the

dust, but binds it, and so prevents rain washing it off. To obtain this binding effect, as stated before, flour size is used as an ingredient in the mixture.

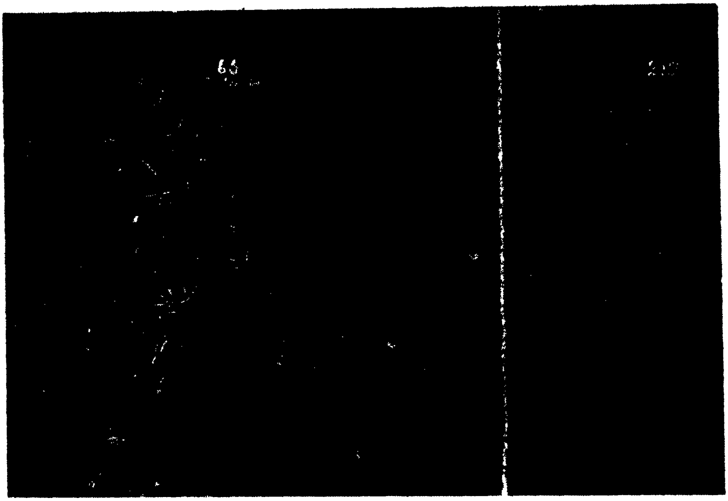

Fig. 8.—Showing *Atriplex nummularia* seed sown on hard uncultivated ground.
Section 65. Seed germinating in mud coats.
Section 210: shows clean seed sown under same conditions and receiving same treatment.

SUMMARY.

After pointing out that most attention has been paid to the propagation of Karroo shrubs under nursery conditions, the writer points out that most efforts to re-seed bare veld have been failures, and summarises the reasons for their failure. A method of coating seed has been achieved of mixing 8 parts of clay loam and 1 part of manure, with flour and seed to the consistency ot plaster mortar with water, spread to a depth of half an inch and raked into small particles and then allowed to dry. The seed is contained in the small particles and germinates very successfully under field conditions. Both grass and shrub seeds have given good results in the field. Nodes of stoloniferous grasses for propagation are treated in the same way with success.

After discussing the necessity of the flour in the mixture, a summary of the advantages gained by mud-coating the seeds is given. The most important of these is that it is cheap, practical and effective.

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NOTES ON TWO IMPORTANT GRASSLAND TYPES IN THE VEREENIGING DISTRICT

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ABSTRACT.

INTRODUCTION.

This work was planned to investigate the course of secondary succession on fallow lands in the Vereeniging district; and to compare, from an economic point of view, the fallow vegetation with the vegetation of the Themeda veld which later takes its place. These two veld types occur with slight variations over a very large area of the southern Transvaal and the north-eastern Free State. As the soil types on which they are found are also very similar to the Vereeniging sandy loams, observations made at Vereeniging should in general be true for the whole area.

STAGES IN THE SUCCESSION FROM FALLOWS TO THEMEDA VELD.

The fallows investigated are found on old maize lands, abandoned after many years of cropping without the addition of fertiliser to replace the plant foods which were removed. When cultivation is discontinued, the lands are colonised by annual weeds, of which the main ones are *Tagetes minuta, Conyza* sp., *Gnaphalium undulatum, Physalis minima*. These seldom persist for more than two years. The dominant types vary from place to place, depending not so much on the conditions under which they must grow as on the stocks of seed available from the commonest weeds in those parts. In fact, by seeding artificially almost any of the successionally advanced grasses can be made to colonise old lands.

The second stage is one of annual grasses, most of which are relished by stock and provide an abundance of good feed towards mid-summer. Several species usually occur together and continue in gradually diminishing numbers as the succession moves forward. The most important ones are *Chloris virgata, Digitaria horizontalis, Urochloa Helopus* and *Setaria pallidifusca.*

The third stage is dominated by *Cynodon dactylon.* It is the most important and useful constituent of the fallows grasses because of its hardiness and persistence for many years, its

dense growth habit which guards against erosion, and the way in which it produces an abundance of excellent feed throughout the summer. Unfortunately these fields of Cynodon are soon spoilt by *Aristida congesta*, which is usually the next grass to migrate in. When once past its earliest stages, no stock will touch it; and by means of its sharp awned seeds it effectively keeps from being grazed, the better species which may be mixed with it. A mixture of Cynodon and Aristida is usually predominant on these old lands for about twenty years.

The fourth stage is characterised by the dominance of a species of *Eragrostis* (nr. *E. curvula*). It forms a characteristic type of tussock veld which is gradually invaded by *Themeda triandra*, becoming less and less important until the veld is finally almost pure Themeda. Although the Themeda veld is not a true climax, it is nevertheless a very stable community, and is for this reason a most important one.

Characteristics of Themeda Veld and Fallows.

Themeda veld is a very uniform type, forming when in flower a dense stand like a field of wheat. Other species are not important. At ground level, Themeda occupies 20 per cent. of the space, and all the other grasses and herbs together 11 per cent., making a total basal cover of 31 per cent. This veld undergoes a striking change when protected. After one season, the Themeda becomes more leafy and flowering is delayed for three weeks or a month. After two seasons' protection, flowering is reduced to 9 per cent. of the normal rate. After this the accumulated amount of dead rubble chokes the plants, and Themeda begins to die out. It is at this stage that a most interesting change occurs—the resulting bare areas are colonised by a rapid spread of *Digitaria milanjiana*. There are indications that one may expect this plant to increase greatly in importance with a few years' protection. The other plants appear to be relatively little affected.

The investigations on fallows are concerned mostly with lands which have been uncultivated for about sixteen years. Their vegetation is not as homogeneous as that of the Themeda veld, being a mixture of *Aristida congesta*, *Cynodon dactylon* and *Eragrostis* spp., and the basal cover is higher because of the frequency of Cynodon—40 per cent. as compared with 31 per cent. Three years' protection on such fallows will cause *Aristida congesta* to disappear almost entirely, but under any form of disturbance it persists with undiminished vigour.

Hyparrhenia hirta and *Tricholaena repens*, which are such a conspicuous feature of the fallows farther north, are exceedingly rare. Wherever Themeda veld similar to the Vereeniging type is found, this type of fallow will be found with it. It is characteristic of the main maize-producing districts, and may be fairly accurately bounded by a line passing through Vereeniging,

Heidelberg, Devon, Bethal, Standerton, Bethlehem, Senekal, Thaba 'Nchu, Bloemfontein, Kroonstad, Vereeniging.

An Economic Comparison of the two Types.

1. *Palatability.*

In this respect there is not much difference between fallows and Themeda veld, except where the fallows contain a great deal of Aristida. The application of ammonium sulphate at a rate of 600 lb. per morgen greatly increased the palatability of Themeda veld. Strips so fertilised were preferentially grazed by the cattle both in summer and in winter, when the grasses were frosted.

2. *Selection.*

This is slight in Themeda veld but most marked in the fallows where it is caused almost entirely by Aristida.

3. *Earliness in Shooting.*

Fallows provide good spring grazing, while the Themeda veld is dormant. They are on the average a fortnight ahead of the Themeda veld.

4. *Carrying Capacity.*

Tests were carried out for two seasons on two undivided blocks of 2½ morgen. During the first season two cattle were carried on each block for about an equal period before their weight began to drop. In the second season the fallows carried the two cattle for 19 weeks and the Themeda veld for 16 weeks. The average gains in live weight per acre for the two seasons were 97·8 lb. in fallows and 85·5 lb. in Themeda veld. The results of this two years' trial, therefore, indicate that one may expect a greater carrying capacity from fallow lands. The reasons for this appear to be firstly that the fallows contain a great deal of Cynodon, which yields a large quantity of food, and secondly that the Themeda is growing on old lands which may still be deficient in the materials necessary for the healthy growth of successionally advanced plants.

5. *Quality of the Grazing.*

Themeda veld gives a more rapid rise in weight than the fallows. The average gain in weight per ox per day was 2·33 lb. in Themeda veld and 2·02 lb. in the fallows. This suggests that although the yield in Themeda veld is poorer, the quality is better.

A Comparison of the Habitat Factors of the Two Types of Veld.

For a detailed study of the habitat factors, two plots were fenced in Themeda veld and fallows, about thirty yards apart, and, except for their vegetation, as nearly alike as possible in every way. The factors were found to differ as follows:—

1. Soil Moisture.

At about fortnightly intervals throughout one year, six soil samples were taken in each plot in the region of the greatest root development. The moisture content of the soil was less in the fallows in 73 per cent. of the cases, irrespective of season or rainfall.

2. Permeability.

This was tested by means of the steel cylinders described by Burger, and is expressed by the time taken for the absorption of 1,000 ccs. of water over a given area. Observations made during autumn and winter indicate that permeability is greater in the fallows, the ratio being about 3 to 2.

3. Soil Temperature.

Readings at 3 inches depth were taken by means of Cambridge Recorders. Both in winter and in summer, the daily maxima for fallows are above those of Themeda veld by an average of 8·6° F. An unexpected fact concerning the minima is that these are consistently lower in the Themeda veld; that is, the blanketing effect which is so noticeable during the day is not manifest at night. Similar conditions have been noted by Flory in America. These results were supported by non-recording mercury thermometers at the surface and at 4 and 18 inch depths.

4. pH.

pH was investigated by the electrometric method, and was found consistently lower in the fallows—6·73 as compared with 7·08.

5. Wilting Point.

By a laboratory method described by Bouyoucos, the wilting point of fallows was found to be lower, the figures being 6·04 and 6·86.

6. Organic Matter.

The amount was found by combustion and was less in the fallow soils, the averages being 4·12 and 3·27 for the two types.

7. Maximum Water-retaining Capacity.

Determinations were made from undisturbed soil according to the method of Bates and Zon. The average for the Themeda veld was slightly higher.

8. Evaporating Power of the Air and Evaporativity.

Readings taken throughout the year were much greater in the fallows. Readings were taken by means of Livingston-Thone atmometers.

9. Air Temperatures.

Results for a year from a hygro-thermograph showed that fallows are on the whole warmer than Themeda veld. The difference is a small one of about 2° F., but is fairly constant.

This was verified both for night and day temperatures by means of an Assmann psychrometer. The temperatures approach very closely to each other during the winter months and tend to diverge again during the summer.

10. Light.

Light values, as measured by Eder-Hecht photometers and the Weston cell, were found to be roughly twice as great in the fallows. The greatest differences were at midday. They were insignificant in the early morning and in the evening.

11. Humidity.

Maximum temperatures from hygro-thermographs were used to obtain the saturation deficit of the two types of veld. The fallows air is in general drier that the air in the Themeda veld. Figures from the Assmann psychrometer were in agreement. After 2 p.m., the differences gradually become less, until the values at about 9 p.m. become the same.

The Influence of some Habitat Factors upon Themeda and Aristida.

The tests carried out with these grasses showed conclusively that they respond very little to varying habitat factors and are therefore unsuitable for use as phytometers. For this purpose, about thirty of each were transplanted into tins. Great difficulty was experienced in getting them to grow, but in the end there were enough for a number of tests to be done.

1. Light.

Wooden frames were covered with one, two and three thicknesses of hessian and placed over the plants in the field. These screens cut down the light to 33 per cent., 15 per cent. and 9 per cent. of the value outside, and the test was continued for two years. In the fallows, Aristida was quickly killed under all the screens. Cynodon continued growing under one and two layers of hessian, but under three layers there was no vegetation at all after the first year.

In the Themeda veld as well, all vegetation was killed under three layers of hessian, and a little Cynodon was all that grew under two layers. The shading under one layer of hessian had a beneficial effect on all the grasses there. They developed a great quantity of leaf, finer and softer than the normal form, and were at all times quite healthy.

Tests carried out on seed germination of Themeda and Aristida showed that moderate and heavy shading had no perceptible effect, but direct sunlight depressed the germination in the case of Themeda and increased that of Aristida.

2. Soil Fertility.

Neither Aristida nor Themeda reacted in any noticeable way when grown in the two different soil types.

3. *Permeability of the Soil.*

All tests were carried out by sowing seed on cultivated soil and on untreated soil. There were no differences with the Aristida, but Themeda showed a more rapid growth rate and was stronger and healthier where the soil had been loosened.

4. *Organic Matter.*

Compost at the rate of 8 tons per morgen had no influence whatsoever on the growth or the palatability of Themeda. Its effect on Aristida was not tested.

5. *Soil pH.*

In an attempt to show the effects of growing these grasses in an alkaline medium, agricultural lime at the rate of 2,000 lb. per morgen was applied to Themeda veld and to fallows. There was no growth response and no increase in palatability.

6. *Atmospheric Humidity.*

Themeda and Aristida were grown under bell-jars in a normal and in a wet atmosphere. The humid conditions affected both adversely. The leaves became pale and discoloured and a general lack in vigour was apparent.

7. *Soil Temperature.*

When the soil temperatures were artificially varied, neither of the two sets of plants showed any response to the different conditions.

SUMMARY.

After the lands have been abandoned, it takes very many years for the Themeda to become dominant, but a comparison of the fallows with the Themeda veld shows that the fallows, even in the very early stages of the succession, provide a great deal of feed which is of quite good quality. Economically there seems little to choose between the two types.

Habitat factors are in general more extreme in the fallows, but do not appear to prevent the Themeda from obtaining a foothold provided that there is seed present. As distinct from the Natal type, it has great difficulty in establishing itself in the reduced light under other vegetation, and probably the other factors mentioned by Bews are responsible for its advanced position in the grassland succession.

The full paper is filed at the Botanical Department, University of the Witwatersrand, Johannesburg.

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A CONTRIBUTION TO OUR KNOWLEDGE OF THE ALGAL FLORA OF THE TRANSVAAL HIGHVELD*

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Introductory Note.

Although in recent years much valuable research has been conducted into the algal flora of Southern Africa, this has been restricted largely to the Cape Province and the coastal regions, where the topography provides for a richer algal flora than that of the Transvaal. Apart from three publications by Nygaard (1932), Rich (1932), and Weintroub (1933), the algal flora of the Transvaal is a field of investigation practically untouched. Since conditions in the Transvaal differ so widely from those prevailing in the areas more thoroughly investigated, it was thought that a study of our algal and general hydrophytic flora would prove of considerable interest. With this object in view, work was commenced in May, 1937, at the Witwatersrand University Botanical Research Station, Frankenwald. Two sites were selected for the purpose of these investigations, the Jukskei River which flows through Frankenwald, and a vlei which is fed throughout the year by the waters of a natural spring.

Technique Employed.

Whenever possible weekly collections of algal and hydrophytic angiosperms were made at Frankenwald, and no interval of longer than two weeks elapsed between collections, so that any appreciable changes in the algal flora would not escape unnoticed. A plankton net of fine silk bolting cloth (No. 20) was employed for collecting in the vlei and the broader parts of the stream, while a scalpel was used for collecting scrapings from the rocks and soil. In the case of stagnant waters, the surface 'bloom' was removed by means of a small pipette. Samples were collected in broad-mouthed test tubes and removed to the laboratory for immediate examination.

Samples were always taken between 8 a.m. and 12 noon, for since the water is so shallow, it was found that there was

* Omitted from 1938 Journal.

nothing to be gained by observations as to which forms were to be found at the surface of the water at different times of the day. This aspect would be of interest in the study of the flora of deeper lakes, but in this case it was of no value, since the penetration of light hardly differed on the surface and on the stream bed.

With every collection, records were made of the temperature of the air, temperature of the water, and rainfall for the week. Since the water is so shallow there was no difference worthy of note between surface and bottom temperatures. The summer temperatures of air and water are seen to maintain a fairly regular correspondence, in spite of the thermal conservatism of water due to its greater specific heat. This is understandable because of the nature of the stream. It flows in many parts in thin sheets over ledges of rock in contact with the air and fully exposed to the sun. The curves for the winter months show less concurrence, presumably because the velocity of flow was less, and the water was often frozen, particularly during the night.

The water-level, colour, odour if any, turbidity, and velocity of flow were noted with each collection. At monthly intervals pH determinations of the water of river and vlei were made by the electrometric method, using quinhydrone and saturated calomel electrodes and the Cambridge hydrogen ion potentiometer. The pH values varied extremely little during the course of the year.

It is unfortunately impossible to name many algae unless the reproductive processes have been observed. Thus it was necessary to keep a number in culture in the laboratory in order to try and induce reproduction, and thus observe the full life-cycle. This is a matter requiring infinite time and patience, since every species seems to react to cultural conditions in a different way. The algae should, of course, be grown as nearly as possible under natural conditions. Filtered rain water or tap water is sometimes a satisfactory medium, for example desmids such as *Closterium* thrive in tap water in diffuse light.

In some cases reproduction may be induced by using a nutritive medium containing rather more of the available raw food materials than is to be found in the natural medium. Algae, however, especially the Isokontae, are very plastic organisms, and if the conditions of the culture are to a large extent abnormal as compared with natural conditions, strange phases and monstrous forms are obtained, and, although these may sometimes give valuable evidence concerning phylogenetic relationships, they are of very little use in determining a species. Solid media, such as agar-agar and gelatin, have often been used for cultural purposes, but these are so far removed from the prevailing conditions in the natural habitat that any results obtained by such means may be regarded as worthless. The

nutritive medium which the writer found to be most satisfactory was Knop's solution.

1000 grammes	H_2O
0·25 gram	$MgSO_4$
1 ,,	$Ca(NO_3)_2$
0·25 ,,	KH_2PO_4
0·12 ,,	KCL
trace of	Fe_2Cl_6

This makes a strength of 0.172 per cent. which is most suitable for cultural purposes.

For the smaller species petri dishes and test tubes were used, but larger algae such as *Spirogyra* and *Oedogonium* require a large quantity of water, preferably one or two gallons. The culture vessels should never be exposed to direct sunlight, and should be kept as cool as possible. Hanging-drop slides were used in an attempt to obtain pure cultures, but these were unsuccessful, presumably because the supply of nourishment was insufficient. The cultures also became infected by bacteria. This, according to Klebs (1896), can be prevented by the addition of 0 01 per cent. of potassium bichromate. The writer found that this addition effectively disposed of the alga as well.

Of all algae to keep under cultural conditions the *Volvocales* give the most trouble. *Pandorina*, *Eudorina* and *Volvox* can be kept for a week or two in a large volume of tap water, but *Pandorina* and *Eudorina* usually occur in such small quantities that, unless in pure culture, they soon give way to forms whose reproductive rate is more rapid.

Certain members of the *Selenastraceae* and *Coelastraceae* thrive in Knop's solution in diffuse light. Species of *Scenedesmus* are particularly easy to cultivate, and may be kept in the laboratory for an indefinite period simply by renewing the supply of Knop's solution at intervals. The investigation of the growth of *Chlorococcales* in cultures has rendered it perfectly clear that a certain proportion of the *Chlorococcales*, while capable of a holophytic existence, possess a strong saprophytic tendency, and attain a much better development under conditions of heterotrophic nutrition. All seem to grow better in cultures to which glucose is added. The loss of green colour is a frequent phenomenon in such cultures provided with organic nutriment.

Ulothrix is difficult to cultivate since it must require very well-aerated water. Similarly in the case of *Stigeoclonium*, it is almost impossible to reproduce artificially the conditions under which it thrives in nature.

Fruiting was induced in *Oedogonium* by keeping the material in Knop's solution in a dark cupboard for a few days. A large volume of water is required for successful cultures.

The *Conjugatae* did not present many difficulties in culture. West (1916) states that conjugation may be induced in *Spirogyra* by exposing the material to the sunlight in a 2-4 per cent. solution of maltose or saccharose. The writer tried this method,

but it was never successful, and conjugation was eventually induced by placing the alga in Knop's solution for a week, and then transferring to distilled water. *Desmids* thrive in tap water if they are not exposed to direct sunlight, and forms such as *Closterium sp.* and *Cosmarium sp.* may be kept in the laboratory for long periods, cell-division occurring at night. Cultures should be neutral or slightly alkaline. The provision of extra nutriment is unfavourable to healthy growth. A large volume of water is required, since if desmids are kept in small vessels for some time the abnormal conditions cause curious cytological changes, resulting in the formation of large vacuoles, which previously did not exist. These vacuoles generally contain numbers of minute moving granules of a pale yellow or brown colour. This is a pathological condition, and is associated with the gradual disintegration of the chloroplasts.

In naming members of the *Bacillariales*, a study of the life-cycle is not essential, so few cultures were needed. They were found to exhibit most active growth in very cold waters.

The *Eugleninеae* when present in large quantities, form a green, or sometimes slightly reddish coating on the sides of the vessel. They can stand a more prolonged exposure to light than many other algae.

Myxophyceae which grow on damp soil, can be kept in the laboratory if they are dug up together with a fair amount of the soil and are kept damp and not exposed to very intense sunlight. Forms which occur in the plankton, such as species of *Anabaena*, cannot be kept alive after collection unless placed in a large volume of water. One or two days in a small vessel is usually sufficient to cause disarticulation of the trichomes, which, under these conditions, often develop forms which are quite unknown in their natural state.

23 species of algae were collected from the stream and 54 from the vlei. A simple key to the genera was compiled.

New Records for Transvaal.

The following forms are, to the writer's knowledge, new records for the Transvaal. It seems unlikely that some of these algae have not been collected before, but there is no mention of them in the available literature.

ISOKONTAE.

Cosmarium granatum Breb.
Oedogonium rufescens Wittr.
Selenastrum gracile Reinsch.
Stigeoclonium lubricum (Dillwyn) Kutzing.

BACILLARIALES.

Fragilaria capucina Kg.
Navicula ambigua Ehrenb
Navicula elliptica Kutz.
Navicula lanceolata Kutz.
Synedra longissima W. Sm.

CYANOPHYCEAE.

Chroococcus dispersus Lemm.
Chroococcus minutus Kutz.
Cylindrospermum cf. stagnale Kutz.
Gleocapsa cf. polydermatica Kutz.
Nostoc commune Vauch.
Oscillatoria limosa Ag.

ECOLOGICAL NOTES.

Except for *Volvox*, members of the *Volvocales* were never present in large numbers. They attain their maximum abundance in quiet waters during the summer months, and were not represented in the plankton at all from May to October. *Asterococcus superbus* appeared in early spring. It is a very resistant form, whose cells were found to have a large starch content. *Chlamydomonas*, *Pandorina* and *Eudorina* were occasional members of the free-floating plankton. West & Fritsch (1927) report that *Eudorina elegans* is most common in Autumn, but at Frankenwald this was not the case, *Eudorina* appearing in the vlei during the summer months. *Volvox Rousletti* appeared in immense quantities with the advent of the first spring rains, flourished for a few weeks, and then disappeared completely. When present in such tremendous quantities, *Volvox* colours the water a bright, transparent, emerald green. Needham (1928) quotes the time of maximum abundance of *Volvox* in American waters as the autumn, but *V. Rousletti* undoubtedly dominates the plankton in early summer. As a reason for the sudden and complete disappearance of the species at the time of its maximum abundance, one can only assume that together with many other less hardy forms, *Volvox* was destroyed during the very heavy rains which fell throughout December. Apart from the purely mechanical force of rain and hail, the concentration of mineral salts in the water would be altered to such an extent that only the most easily adaptable forms could survive. Fritsch (1935) reports that *Volvox* in large quantities imparts an unpleasant odour to the water, but although *V. Rouseletti* was present in huge numbers, there was no disagreeable result.

The *Chlorococcales* also, are most abundant during the maximum heat of midsummer, but they are more hardy organisms than the *Volvocales*, and some forms, such as *Scenedesmus*, are also found during the winter months. *Crucigenia* and *Oocystis* are common amongst the shore vegetation, but are also found in the plankton of still, open waters. *Tetraedron* and *Ankistrodesmus* appear to be common in shaded waters, while *Selenastrum* favours the margins where it is frequent among other water-plants. *Scenedesmus* shows a marked preference for stagnant waters. It is commonly considered that all algae pollute water, but the majority of fresh water algae, and I think, particularly the *Chlorococcales*, tend rather towards the purification than otherwise of water, owing to their capacity to absorb and utilise many kinds of organic substances.

Ulothrix punctata and *Stigeoclonium lubricum* are characteristic of waterfalls. *Ulothrix* occurs in early spring, but was only found very rarely.

The adult plants of *Oedogonium* occur floating in masses in quiet waters, or attached to rocks or various aquatic plants. In the Jukskei River *Oedogonium* sometimes occurs attached to the bank and floats out into the stream in strands, often as much as two yards in length. As the mucous covering on the filaments is only very slightly developed, they do not feel as slimy as most filamentous green algae, and afford a substratum for various epiphytes, particularly the diatom *Gomphonema gracile var. lanceolata*, which is very common. In the autumn and winter the cells were found to have a very high starch content, and the time of maximum abundance coincided with the first spells of bright sunshine in the spring.

Most authorities are of the opinion that the periodicity of *Spirogyra* may be directly correlated with changes in temperature, but the writer found a much closer correspondence between the growth of *Spirogyra* and the rainfall. As the water-level receded, masses of *Spirogyra* were left on the banks and rocks, and were dried out. The temperature was quite high enough to support the healthy growth of the alga, but, as is clearly seen in culture, *Spirogyra* requires a large volume of water, and that present in the river was insufficient.

Spirogyra, *Zygnema* and *Oedogonium* differ from true plankton by floating on the surface of the water, thus being adapted to an existence in contact with the air. Warming (1909) places these plants in a separate category, the hydrocharid formation or pleuston.

Being unattached, *Spirogyra and Zygnema* prefer still waters, where they occur as bright green flocculent masses on the surface, and, during the winter months, in smaller amounts on the bottom. In midsummer the flocculent masses were observed to change colour gradually from bright green to yellow, mostly owing to the death of a large proportion of the filaments as a result of exposure to light of too great an intensity.

Needham (1928) says of the American species of *Spirogyra* 'their rather large filaments form a solid support for hosts of lesser sessile algae.' In the species of *Spirogyra* present at Frankenwald the mucilage envelope is so well-developed that no epiphyte could possibly become attached to the filaments. Transeau (1908) finds that in *Spirogyra*, and probably also in *Oedogonium*, the time interval elapsing between the first appearance of the species and the commencement of sexual reproduction depends on the temperature and the specific surface (i.e., total surface divided by volume). *Spirogyra* at Frankenwald conjugates in autumn, but the alga is present in the water throughout the year, although it shows a distinct decrease during the dry season.

Asexual reproduction in the *Conjugatae*, as in a number of other forms, seems to coincide with the time of maximum abundance, and very often, though not always, it marks the end of the period of active growth, and is followed by more or less complete disappearance of the form involved.

It is highly possible that the complexity of outline of many desmids, accompanied by a defensive armour of spines, has been acquired as a means of defence against the attacks of small aquatic animals. It is a noticeable fact that the majority of these species which occurred on rocks and in other situations in which *Oligochaetes* and *Crustacea* are either absent or scanty, usually possess a comparatively simple outline, whereas those occurring in the plankton of the vlei and at the quiet margins of the stream, in which such enemies abound, have a more formidable exterior. West (1916) is of the opinion that the hooks are also of use as anchors in times of flood, but during the heavy rains of December, no desmids survived at Frankenwald. Desmids flourish in neutral, or slightly alkaline waters, and are present in small quantities throughout the year.

Diatoms were plentiful at all seasons, but were more abundant during warmer weather. They form a yellowish-brown scum at the surface, or a sediment at the bottom, or thickly clothe other algae and aquatic plants. They are frequently found intermixed with the scum of living or decayed vegetation floating on the surface of the water. In the vlei they seemed to show a decided preference for cool shaded spots.

The *Eugleninae* are known to prefer waters rich in organic nutriment and harbouring abundant vegetation. The irregular appearance of *Euglena* often follows immediately on the periodical dying away of the filamentous algae. Thus when *Spirogyra* and *Oedogonium* were at their minimum, *Euglena* was most abundant. The resting stages of *Euglena* often formed a conspicuous red coating on drying mud, or on the stems of sedges in the middle of the vlei.

The *Myxophyceae* are distinctly hot weather forms. They are common on damp soil and in the plankton, and in sunlight possess an enormous reproductive capacity. *Oscillatoria* and *Lyngbya* grow in dense, brightly coloured tufts on and at the water's edge, and as patches of very slender filaments attached to the bottoms and sides of warm stagnant pools. They thickly cover patches of the muddy bottom, and the formation of gases beneath them disrupts their attachment, and the broken flakes of bottom slime that they hold together rise to the surface and float there. *Oscillatoria* and *Lyngbya* also occur as detached filaments floating freely in the open water, and during the warmer portion of the year are common constituents of the plankton. The trichomes of *Lyngbya* are often very densely intertwined.

Merismopedia also drifts about freely in the open water, but rarely in abundance. It sometimes settles on the leaves of the larger water plants.

Cylindrospermun, *Gleocapsa* and *Chroococcus* often occur together, forming a thin film on damp soil, or rocks over which the water trickles very slowly. They are characteristic of communities consisting of blue-green algae only, and are rarely found in the plankton.

Nostoc forms leathery or slimy gelatinous masses, at first spherical or oblong, but later of varied form, solid or hollow. They are attached or unattached, and are to be found on damp ground. *Anabaena* is never as large and tough as *Nostoc*, and occurs free-floating in the plankton, or aggregated to form a thin stratum on damp soil.

Even a cursory glance at the enumeration of samples listed gave clear evidence of the far richer algal flora to be found in the vlei than in the river. The undisturbed waters of the vlei allow for the full and healthy development of a large variety of species, whereas in the river, especially in the summer, the plankton seems to be washed away before the opportunity for reproduction occurs. A careful study of the times of maximum abundance of algae in the vlei in successive years would shed much light on the conditions, determining their development. but after only one year of study no conclusions can be drawn with safety. It is probable that temperature, pH, aeration of the water, and the amount of dissolved mineral and organic substances in the water are leading influential factors.

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My thanks are due to Professor John Phillips, at whose suggestion these investigations were undertaken, and in whose department I have worked. I also wish to express my gratitude to Mrs. M. Moss for general advice and encouragement, to Miss D. Weintroub for the loan of her collection of Witwatersrand algae, and to Mr. A. H. Bunting for doing pH determinations.

SUMMARY.

Weekly collections of algae were made from the Jukskei River and a vlei at Frankenwald. It was possible to name certain specimens immediately, but others were kept in culture in order to study the life-cycles. The algal flora of the river was found to be very poor, only 23 species being recorded, as compared with 54 species in the vlei. The velocity of flow of the stream was the chief reason for this discrepancy. Data of ecological interest were noted, and the lines on which further research might be conducted are indicated.

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ALBINISM IN A MALE VERVET MONKEY, *CERCOPITHECUS PYGERYTHRUS*

BY

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With 2 Text Figures.

Read 3 July, 1939.

Our department has been fortunate in recently acquiring a male albino *Cercopithecus pygerythrus.* The albinism is congenital and apparently permanent. He was transferred from the Johannesburg Zoological Gardens as he could not defend himself well against other vervets because of his poor eyesight.

It is the purpose of this paper to record the features of this case and to show how they elucidate certain aspects of albinism.

Description.

The whole fur of the animal is completely white (Fig. 1, B.). None of the pattern, which normally characterises this species, is discernible. Individual hairs are longer, thicker and stiffer than in the normal animal.

Practically the whole skin is unpigmented. It has a typical pink colour, attributable to its vascularisation. The normal vervet has a dark skin, which is blackest over the ears, muzzle, lips, nipples, palms and soles. In these areas, where the skin is exposed, the contrast between the albino and normal vervet is particularly striking. (Fig. 1.)

The pigmentation of the scrotum and the mammary glands, which is a characteristic, bright blue colour in the normal vervet, is represented in this albino by a paler shade of blue. But the skin of the glans penis and prepuce is a vivid scarlet, as in the normal vervet. The colouration of the perineal skin is also normal.

There is some pigmentation of the tongue, gums and cheeks in the normal monkey, not sufficient, however, to mask the pink colour. This pigment is absent from the albino. The only evidence of melanin formation in this vervet is the sporadic appearance and disappearance of brownish patches along the muco-cutaneous junction of his lips.

In the normal vervet and baboon the iris and the sclera are darkly pigmented (Fig. 1, A), while in the albino the iris is unpigmented and sclera has a milky white colour. If seen in a subdued light, when the iris appears as a greyish film, the

white sclera and the pale pink eyelids contribute to render the appearance of the eyes remarkably like that of the human being. (Fig. 1, B.)

Fig. 1.

A. B.

There is also intense photophobia. Within the shadows of his cage the albino appears fairly comfortable. But even here his pupils are contracted to about half or less than half the diameter of those of other vervets under the same light conditions. When suddenly brought outside it is generally impossible for the first few minutes to persuade him to look up and often he lies face downwards, as illustrated in Fig. 2, A. If one tries to pull on his chain at this stage he becomes very angry, but he does not lift his head. (The normal vervet attacks actively with face thrust forward when annoyed, as illustrated in Fig. 1, A.) After a while he may sit up with his eyes closed (Fig. 2, B). When he eventually is able to tolerate the light (Fig. 2, C), there is pinpoint contraction of his pupils.

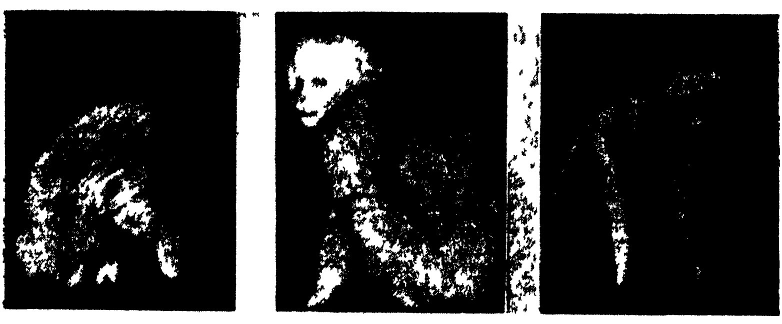

Fig. 2.

A. B. C.

Associated with apparently gross interference with vision there is very severe nystagmus. The nystagmus is chiefly horizontal, but slight circular nystagmoid movements have also been observed. Nystagmus is constantly present, but is aggravated by attempts to focus on nearby objects and by conjugate deviation of the eyes. When gazing at a distant object nystagmus decreases. If the eyes are deviated to any side the rapid component of the nystagmoid movements occurs towards that side; the slow drifting movements are towards the position of rest.

The normal vervet is capable of looking directly at a nearby object. The albino tilts his head in such a way that he inspects the object with his eyes deviated to one or other side (Fig. 1, B), apparently finding it easier to recognise the object in this way, in spite of the marked nystagmus, which occurs with the eyes in this position. Even with these efforts, however, when reaching out for the object his aim is not as certain as that of the normally pigmented monkey.

There is considerable bagginess of the tissues below the eyes (Fig. 1, B), no doubt caused by constant eyestrain.

Ophthalmoscopic examinations performed under ether anaesthesia revealed the following: The "scleral" pigmentation of the normal baboon and vervet is superficial, i.e. actually in the conjunctiva. In the albino no melanin is seen in the conjunctiva, sclera, iris or fundus. In the normal monkey the fundus has a greyish appearance, the optic disc is white at the periphery, pink in the centre and relatively deep. No macula lutea is discerned, though the macular bloodvessels are developed to the same extent as in the human fundus, thus suggesting that a macula exists. In the albino the fundus is a bright pink, either due to retinal congestion or to the vascular choroid coat shining through. The retinal bloodvessels are wider than normal and irregular. The optic cup is pink and poorly demarcated from the rest of the retina. The macular veins and arteries are conspicuous, but the macula cannot be detected. The lens and cornea are normal and the iris completely transparent.

On placing a black diaphragm with an aperture up to three millimetres in diameter in front of the eyes, the pupil appeared black even with a strong beam of light shining directly into the eye. With apertures wider than about five millimetres the fundal reflection again became pink. This experiment confirms the work of Donders (1854) quoted by Duke-Elder (1932).

Within the first quarter of an hour after recovery from the general anaesthetic, nystagmus was absent, ostensibly owing to absence of efforts to accommodate the eyes.

In stature and development the albino appears on the whole normal. His behaviour corresponds to that of other vervets, and no evidence of impairment of intellect has been obtained. He is rather more excitable than our other monkeys, but this is in keeping with the fact that he has not been correspondingly tamed. Slight irregularity of the lower incisor teeth (which may be an

acquired feature) and arachnodactyly affecting all the digits except the thumbs, the big and little toes and the left middle finger are also present. The latter is abnormally short and without a nail. The hands and feet are also kept open with the digits extended while at rest. In the normal vervet the hands are usually held closed when not in use.

Discussion.

The Incidence of Albinism among Animals.

Albinism manifests itself as either a sporadic or an endemic condition. It is transmitted as a Mendelian recessive character. It is accompanied by ocular deformities, visual defects and somatic dystrophies in the sporadic cases. While it may remain latent in many generations, union of parents both having the recessive character, but heterozygous for the albinism, may render it apparent in the offspring. In the same family several albinos may occur, normal and abnormal children often alternating. Sporadic albinism in man occurs as either a *simple recessive* type, with an incidence of about one in every twenty to thirty thousand, males being most frequently affected, or a *sex-linked recessive* form, transmitted by apparently normal females in a manner comparable to that in which *Haemophilia* is transmitted. (Cockayne, 1936.)

Endemic albinism is so frequently found among certain types of mammals that one tends to overlook the fact that these are true albinos. According to the permanency and specificity of the albinism several grades may be recognised. At one extreme may be placed animals such as the Arctic fox, which is brown in summer, but becomes a pure white in winter. (Wells, Huxley and Wells, 1928.) Eye changes apparently do not occur. At the other extreme of this series are animals such as the albino mice, rats and rabbits. With these the albinism has become a permanent feature, converting them into distinctive species, which do not regularly mix with differently coloured types. In the tropics albino rats may, however, also acquire a rusty pigmentation of the fur (Clark, 1932), whereas the Himalayan rabbit may turn black when kept in the cold. (Crew, 1929.) The albino guinea pig can be readily crossed with the darker coloured guinea pigs, the offspring being piebald. Such albinos would then be of an intermediate type.

Albinism is even less common in lower primates than in man. Haagner (1920), Fitzsimons (1924), and Boulenger (1936a) referred to albinism in the vervet. The latter author also illustrates an albino slow loris lemur (*Nycticebus coucang*). No instance of albinism amongst the anthropoids has been found recorded.

Wells, Huxley and Wells illustrate two wild albino Virginian opassums. Their eyes appear to be normal. Albinism is recorded in the tree porcupine and squirrel by Crew.

Albino birds with pink eyes are not uncommon. (Lull, 1929, Crew.)

Waite describes a case of perfect albinism in the Australian sleeping lizard, *Trachysaurus rugosus*. Boulenger (1936b) admits the rarity of albinism in reptiles, but refers to cases observed in *Tropidonotus natrix*, *Tropidonotus tesselatus*, *Coluber longissimus* and *Coronella austriaca*. In all these the black pigment of the eye was also absent.

Whether the unpigmented cave-salamanders, *Typhlomolge rathbuni* and *Proteus anguineus* should be regarded as albino amphibians is not yet certain. Gadow (1909) states that the skin of *Proteus anguineus* is almost as susceptible to light as a photographic plate. If kept exposed to a strong light the whole animal turns black. Sporadic albinism, on the contrary, is permanent. Cases of albinism in frogs and tadpoles occur as a great rarity. Several specimens, some with pink eyes, have been described by Eales (1933).

Unpigmented fishes and invertebrates are known, but are rare (Lull, Crew.)

Characters of Other Albino Vervets.

The albinism previously recorded in vervets has not always been complete. The specimen described by Fitzsimons had a black face, and the appearance of the eyes suggests pigmentation of the conjunctiva as well as the iris. In Boulenger's specimen the conjunctiva is unpigmented. In this case the hair was also coarse and long. Defective eyesight is evident in the vervet illustrated by Haagner. Fitzsimons' specimen is shown to gaze forward in the normal way, which our monkey was unable to do. In Boulenger's case the eyes converge normally and there is no evidence of nystagmus. Arachnodactyly has not been previously recorded.

The Nature of Albinism.

Lull maintains that albinos are white because the tiny spaces, normally filled with melanin granules, are full of air, which reflects all the light rays. Authors are generally in agreement that albinism is due to deficiency of melanin rather than masking of the pigment. Albinism may, however, signify only a relative deficiency of melanin. (Cockayne.)

The possibility that albinism is due to a deficiency of the oxydase enzymes responsible for the formation of melanin, rather than lack of the tyrosine, tryptophane or phenylalanine precursors of the melanin itself, has to the knowledge of the author not yet been put forward as a theoretical explanation for albinism. Our specimen has revealed the significant fact that the loss of pigment affects the melanin only and not the blue or scarlet pigments. It is argued that if certain colours can still be formed, the raw materials for pigments in general must be present, but the enzymes, which are necessary for melanin formation, are absent.

The growth of hair in the albino is apparently also affected. The hair of the human albino has a silky texture (Ormsby), and

many albinos have a profuse downy growth of soft, white hair all over the body. (Cockayne.) In our vervet the hair is coarser, longer and thicker than in the normal. These hair changes may, however, be completely unrelated to the albinism although associated with it. Wells, Huxley and Wells quote experiments in which albino guinea pigs, which resulted from the crossing of long and coarse-haired albinos with short, smooth and soft-haired specimens, had short, smooth, soft hair. Hair texture must obviously, then, be a separate gene. Other modifications present in the albino, of which the visual defects are the most conspicuous, may, by analogy, also be independent Mendelian recessive characters, which manifest themselves as the result of consanguinity of the parents. Indeed, Cockayne suggests that the intellectual inferiority, deaf mutism, diminished stature and subnormal physique, which are sometimes found in human albinos, may be brought about in this manner. The arachnodactyly of our vervet may fall within this category.

The Explanation of the Eye Manifestations.

While certain authors claim that the albinotic eye is pink because the red blood columns of the iris are exposed to view, as the pigment is defective over both surfaces of the iris (Walter, 1928), others maintain that this pinkness must be attributed to the retinal reflection for it includes the pupil. Some authors state that the choroid is devoid of pigment, thus rendering the pupil red or pink. (Ormsby and Cockayne.) According to Duke-Elder, however, light enters the albino eye not only through the pupil, but, owing to the lack of uveal pigment, also through the semi-transparent iris and sclera. Entering thus irregularly, it is reflected back irregularly. This is necessary to produce the pink reflection. That this is essentially true is proved by the results of the artificial pupil experiment. This experiment also incidentally shows that the pigmentation of the choroid coat has little to do with the redness of the reflection for, whether it be present or not, the pupil appears black if the iris is opaque. In this respect it differs from the tapetum lucidum and the argentea.

Photophobia, which is so conspicuous in our vervet, is present also in many human albinos, but is absent from animals with endemic albinism, even when exposed suddenly to very bright lights. Photophobia would seem to be related to the futility of the transparent iris, which leaves the retina exposed to the irritant effect of too much light. The congestion of the fundus may be due to this irritation. The slow loris lemur suffers naturally from photophobia, because of the way its eyes project. It protects its eyes with its hands when in the presence of bright light. In the albino slow loris, described by Boulenger, this photophobia is greatly aggravated.

Nystagmus is the third type of visual disturbance commonly seen in human albinos and present also in our case. Cockayne claims that the nystagmus is horizontal only, but in the vervet

circular nystagmus is also present. Duke-Elder says that vertical nystagmus is also encountered in albinism. He proceeds to state that the nystagmus of albinism is of a pendular type, becoming jerky when the eyes are deviated to either side. In the present case the horizontal nystagmus consists of alternating rapid and slow movements at all stages. Only in the rotatory nystagmus are both excursions equally rapid. Duke-Elder refers to the condition as amblyopic nystagmus, for it is the type associated with conditions in which vision is gravely affected and fixation is impossible, owing to opacities in the media, refractive errors of the lens and cornea, or a central scotoma due to a defective fovea centralis. Though such defects occur in the human albino (Cockayne) they are not present in our vervet. Vision is probably defective because the neural or vascular elements of the retina have been injured by prolonged exposure to bright light. Our observation that nystagmus is much diminished when gazing at distant objects, suggests that the mechanism of the nystagmus is comparable to that of miners' nystagmus, which occurs because the eyes have been previously accustomed to diverge slightly, as the periphery of the retina is more useful in subdued light. With subsequent convergence of the eyes again to use the macula lutea, when in brighter light, the neural mechanism necessary for this act is found to have deteriorated in efficiency so that fixation cannot occur. As also in our vervet the nystagmus is then aggravated the nearer the object is brought to the eyes. If nystagmus is associated with defective central vision it has, in our opinion, the above mechanism.

Nystagmus has so far only been described for the human albino and the vervet in question. It certainly does not occur in animals with endemic albinism. Nystagmus is thus evidently only found in albino animals with stereoscopic vision. It is then natural also that it should be greatly affected by conjugate deviation and convergence of the eyes.

Summary.

A male albino *Cercopithecus pygerythrus* is described. Complete blanching of the hair and integument (with the exception of the blue and red pigments of the mammary glands, genitalia and perineum) is present. The eyes are pink, vision is defective, gross horizontal and slight rotatary nystagumus and severe photophobia are present. Ophthalmoscopically complete absence of eye pigmentation and congestion of the retina and optic cup are revealed. There is arachnodactyly.

Endemic and sporadic types of albinism are recognised. In the former various grades are suggested, depending on the permanency and specificity of the albinism. Sporadic albinism is a distinctly uncommon variaton, but cases have occurred in every vertebrate phylum.

Only the melanin production is affected. This may be of the nature of defective action of the oxydase enzymes synthesising the melanin rather than lack of melanogen precursors.

It is probable that the dystrophies associated with the albinism may be entirely separate Mendelian characters, which only manifest themselves as the result of consanguinity of parents.

The mechanism of the nystagmus of this case is comparable with that of miners' nystagmus. It may also be related to the stereoscopic vision of the animal types in which it occurs, and is therefore worse with conjugate deviation and convergence of the eyes.

ACKNOWLEDGMENTS.

I wish to thank Dr. J. Gillman for kindly allowing me to study this albino and for his advice. I am indebted to Professor R. A. Dart for various suggestions and for research facilities provided in his department.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVI, pp. 359-363, December, 1939.*

OBSERVATIONS ON THE MODE OF CONNECTION BETWEEN NUCLEOLUS AND CHROMOCENTRE IN SALIVARY GLAND NUCLEI OF SOME SOUTH AFRICAN DROSOPHILIDS

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Communicated by MARY R. MCEWAN.

With 6 Text Figures.

Read 3 July, 1939.

Recent advances in the knowledge of the life history of the nucleolus, especially with regard to the production of this body by satellite and other chromosomes during telophase, have caused renewed interest in its probable function.

Evidence has again been brought forward that during prophase, chromosomes increase in size and staining capacity at the expense of the nucleolus, which gradually dwindles away and loses staining properties. Recent observations have confirmed the older statement that in some cases there exists a contiguity between nucleolus and chromosomes during prophase, although in other cases the nucleolar material may become dissolved in the karyolymph.

According to latest observations, the chromosomes must be looked upon as essentially composed of threads or chromonemata (carrying the genoplasma) surrounded by a matrix composed of kalymmatin. (Heitz, 1935.) Furthermore, chemical analysis indicates a great resemblance between the nucleolar material and kalymmatin. (Marshak, 1931.)

These facts have revived the old theory which endowed the nucleolus with the function of nourishing the chromosomes. In its new form this theory states that during prophase the genes can, as enzyme substances, take from the matrix on the basis of their colloidal selective properties the specific substances they need for their growth and reproduction. The matrix, again, obtains its nourishment from the nucleolus. During telophase some of the ground substance, possibly in a transformed form, is "secreted" (e.g. by the satellite chromosomes) as nucleolar bodies which might flow together to form one large nucleolus of the resting nucleus.

The salivary gland nuclei of Drosophila are of special interest in this connection. In full-grown larvae these nuclei represent the early prophase or spireme stage of mitosis. (Bauer, 1935, 1936; Frolowa, 1938.)

The proximal ends of the chromosomes are heterochromatic, and these regions are near and on either side of the place of attachment of the spindle-fibre in the rod-shaped chromosomes and armed chromosomes respectively. During telophase these regions come in close contact, and fuse to form the chromocentre (Heitz, 1933) of the resting and early prophase nuclei as found in older larvae. The nucleolus is attached to the chromocentre by what is generally considered to be a thread. This thread is formed during transition from telophase to resting nucleus. (Frolowa, 1938.) Its nature is not yet clear.

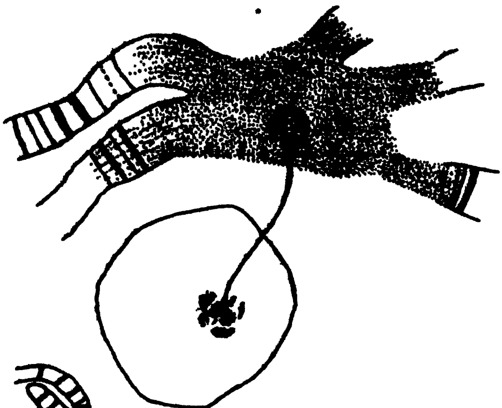
Observations made in the Genetics Laboratory of the University of the Witwatersrand on several local Drosophilids suggest that this thread connecting the nucleolus to the chromocentre must be considered tubular in structure. This, as will be pointed out, has a direct bearing on the revived theory of nucleolar function.

Clear evidence of the tubular structure of the nucleolar thread has been obtained from salivary gland nuclei, especially of three local Drosophilids, two *Zaprionus species* and *Drosophila funebris Fabricius*. Indications of such tubular threads are seen in Figs. 1, 2 a and b, and 3. In Fig. 1 the connection between nucleolus and chromocentre is clearly funnel-shaped at the chromocentral end, where irregular circles represent the place of attachment of the thread. Fig. 2a also shows a distinct mark at the chromocentral attachment of the thread.

In nuclei where the thread is straight its middle region is seen to be thinner than the regions towards the extremities. When the thread is wavy, however, its diameter is thicker throughout its entire length. Compare Figs. 2b and 2a.

These different forms of the thread may be expected when the thread is looked upon as a thin-walled tube—in the former case in a stretched and in the latter in a relaxed condition. If a thin walled rubber tube is attached at each end flush with the surface of an object and the two objects moved apart so that the rubber has to stretch, then its diameter in the middle region will be smaller than towards the respective places of attachment. Such funnel-shaped extremities of the thread are shown in Figs. 1 and 3a.

The nucleolus itself also offers evidence of the tubular structure of the thread. In many cases where the place of attachment of the thread is visible a number of lines converge from the nucleolus to the thread, a characteristic feature distinct also in Frolowa's generalised drawing of the spireme nucleus. (Frolowa, 1936.) It is often possible to see that the nucleolar surface is here somewhat conically raised and possibly continuous



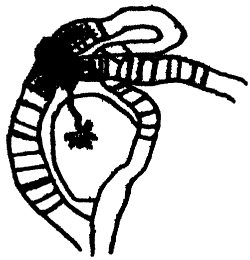


Fig. 2a.

Fig. 1.

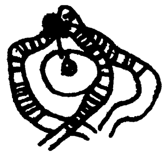
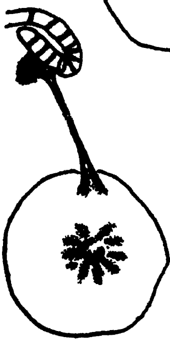
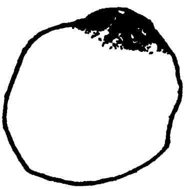
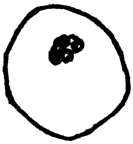


Fig. 2b.







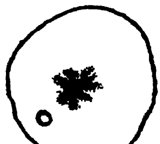
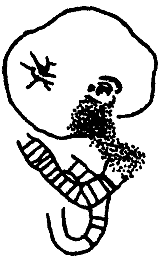


Fig. 3a. Fig. 3b. Fig. 4a. Fig. 4b.



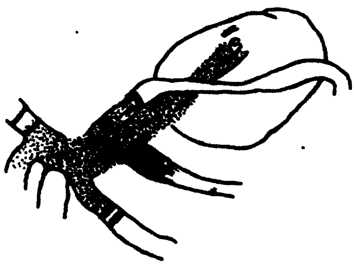
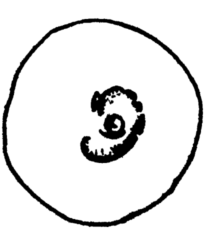


Fig. 5a. Fig. 5b.



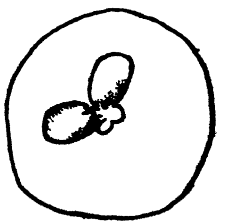


Fig. 6a. Fig. 6b.

Nucleoli from salivary gland nuclei, showing the thread, stress lines and chromocentre. Figs. 1; 2a and b; 6a and b from *Drosophila funebris* Fabr. culture. Figs. 3a and b from *Zaprionus*—tuberculatus Mall. Figs. 4d and b; 5a and b from *Drosophila immigrans* Sturt. culture.

with the thread. These lines are strongly reminiscent of longitudinal creases or folds having their distal origins on the surface of the nucleolus surrounding the exit of the thread and converging towards it. (Figs. 2a, 3b.) Such a configuration will obtain if a thin-walled rubber balloon with a thin-walled inlet-tube is filled with water and suspended by the top of the tube. The converging lines on the surface of the nucleolus, therefore, seem to indicate lines of stress.

It is possible in most cases to detect lines of stress although they may take on different forms than radiating lines. In *Drosophila immigrans* Sturt. these lines seem to be irregular, often containing small vacuoles (Fig. 4a), while in some cases the chromocentre itself seems to be connected to the nucleolus by means of a broad bridge (Figs. 5, a and b). Sometimes two separate figures are seen on the same nucleolus (Figs. 4b, 5a). Spiral stress lines were also seen (Fig. 6a).

The above observations seem to justify the conclusion that the connection between nucleolus and chromocentre is of a tubular nature. If this is so, then the whole morphological arrangement of these salivary gland nuclei may be considered as additional evidence that during prophase nucleolar substance passes from the nucleolus as ground substance of the kalymma, from which the genes ultimately derive their nourishment. Not only does it impart meaning to the chromocentre but also to the position of the nucleolus, perhaps even to the synaptic condition of the chromosomes. The whole arrangement will supply an economical mechanism of distribution of nucleolar material. From the nucleolus as a reservoir the contents pass via the nucleolar tube towards a common distributing centre, the chromocentre, which supplies the matrix of each conjugated pair of chromosomes. It is fully realised that these nuclei do not divide any further, but on the other hand they may be looked upon as nuclei arrested in the act of preparatory division. Furthermore, it is not improbable that the genes in these spireme nuclei are still exerting an important influence, i.e. they may still be needing nourishment.

We are greatly indebted to Prof. Sturtevant, of the California Institute of Technology, for identifying several Drosophilids for our department.

SUMMARY.

Observations on salivary gland nuclei of some South African Drosophilid stocks kept in the Department of Zoology of the Witwatersrand seem to indicate that the thread connecting the nucleolus to the chromocentre is of a tubular nature. If this is so, then the whole morphological arrangement of these salivary gland nuclei may be considered as additional evidence that during prophase nucleolar substance is passing from the nucleolus to the chromocentre as ground substance of the chromosomal matrix or kalymma, from which again, the genes ultimately derive their nourishment.

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South African Journal of Science, *Vol. XXXVI, p. 364, December, 1939.*

THE DENTITION OF SOUTH AFRICAN FISHES AND REPTILES WITH SPECIAL REFERENCE TO THE REPLACEMENT OF THEIR TEETH

BY

F. Gordon Cawston, Durban.

Read 3 July, 1939.

Abstract.

This is an attempt to make accessible, facts the author has observed personally in a study of carefully identified marine and fresh-water fishes, snakes and other reptiles from the Cape Province and Natal.

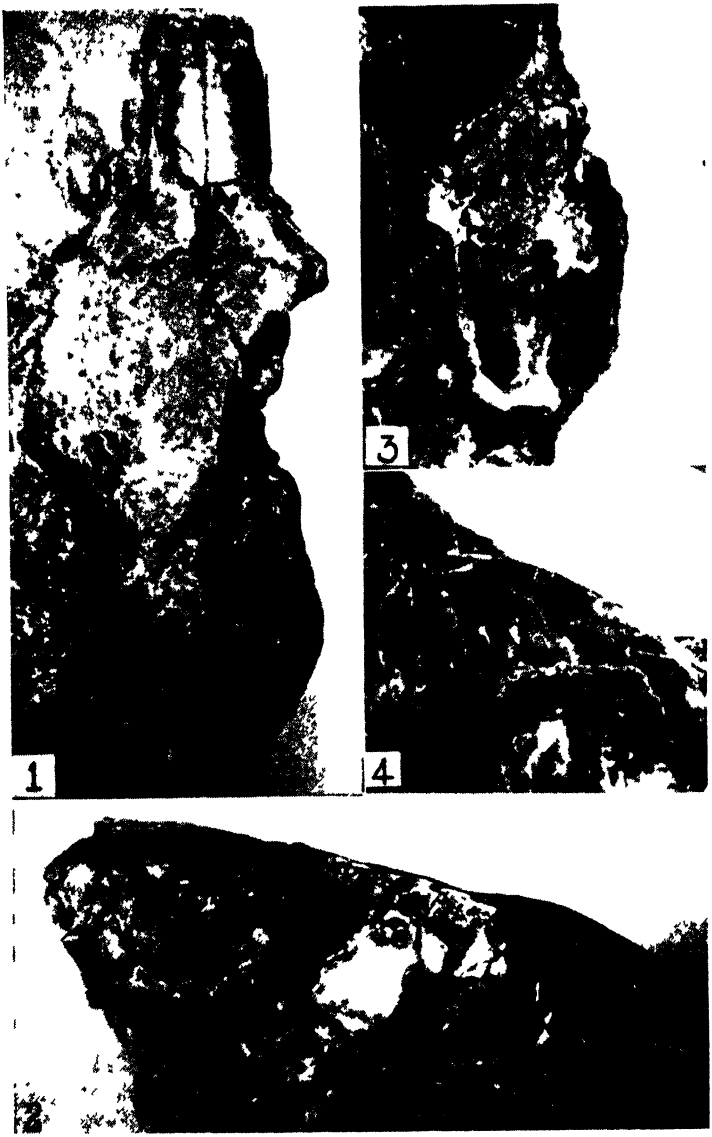
The full paper is illustrated by diagrams of the teeth of nine species of fishes and sharks and ten reptiles. Others have illutrated *gill rakers* and the development of *denticles*.

X-ray photographs by Doctor J. E. W. Graham, including that of a young crocodile, showed vertical succession of teeth in fishes and lizards. This pointed to the conclusion that the small teeth found loose in the gums of some lizards and snakes, lying parallel to the functional teeth, are not successional, but correspond to the hinder teeth of fishes in which there is no replacement other than by vertical succession.

Dissection of the jaw of *Pagrus nasutus* (Cast.) revealed the successional teeth which were also visible in X-ray photographs of various fishes.

Replacement of teeth in many species of fishes and reptiles appears from this investigation to be limited to the young, though in some fishes there is continuous vertical replacement throughout life.

The dentition of venomous and non-poisonous snakes is illustrated by mounted specimens of teeth from material supplied by the Durban, Botha's Hill and Port Elizabeth Snake Parks and from the Natal Estates. Some of the lizards were supplied by the Albany Museum and Mr. J. W. Bell Marley kindly identified the fishes.



The Endocranial Cast in Living and Fossil Hyraces.

1. Dorsal view of skull and endocranial cast of *Procavia transvaalensis* (cf. Fig. 2A).
2. Lateral view of skull and endocranial cast of *Procavia transvaalensis* (cf. Fig. 2B).
3. Dorsal view of skull and endocranial cast of "*Hyrax*" sp. (cf. Fig. 2C)
4. Lateral view of skull and endocranial cast of "*Hyrax*" sp. (cf. Fig. 2D).

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South African Journal of Science, *Vol. XXXVI, pp. 365-373, December, 1939.*

THE ENDOCRANIAL CAST IN RECENT AND FOSSIL HYRACES (*PROCAVIIDAE*)

BY

L. H. Wells,

Junior Lecturer in Anatomy, University of the Witwatersrand, Johannesburg.

With Plate I. and 2 Text Figures.

Read 3 July, 1939.

Introduction.

I have recently had the opportunity of examining two fossil Hyracoid skulls of Early or Middle Pleistocene age from limestone deposits near Krugersdorp, Transvaal, in each of which a natural endocranial cast (as defined by Black, 1920) is partially exposed. One of these is that of the large type described by Middleton Shaw (1937) as *Procavia transvaalensis*. In this specimen (Plate I., 1 and 2) nearly the whole of the superior and lateral aspects of the right half of the cerebrum are visible; the brain-stem and cerebellum are broken off just behind the transverse sinuses. The second skull is that of a much smaller type discovered by Dr. R. Broom, which he is at present unable to name specifically. It will be referred to in this study as "*Hyrax*" sp. Considerable portions of the superior and right lateral aspects of the cerebral region are displayed in this fossil (Plate I., 3 and 4).

In order to elucidate the features displayed by these fossil specimens, endocranial casts have been made from a series of skulls of recent Hyraces, and compared with the brains removed from the same skulls. This series comprises one adult male and four adult females of *Procavia capensis coombsi*, and two adult males and one immature female of *Heterohyrax brucei*, from the Limpopo Valley west of Messina.

Description of the Material.

1. *Size and Form.*

In Table I. certain measurements of the recent and fossil skulls used in this study are set out; these furnish an indication of the general proportions of the types whose brains are to be compared. The dimensions of the *P. capensis coombsi* skulls show a reasonable consistency, being appreciably larger than those of *P. capensis* from the more southerly portions of the Union. Adult skulls of *H. brucei*, though distinctly smaller than those of *P. capensis coombsi*, do not indicate any obvious difference in form between the two types.

TABLE

Measurement of Skulls and Endocranial Casts of Hyraces.

Species	Number of Specimens	Age	Sex	Total Length	Length of Nasal Bones	Height of Premaxilla	Length of Frontal Bones	Supraorbital Width	Dental Length	Length of Cerebrum	Breadth of Cerebrum	Height of Cerebrum
				mm	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
P. capensis coombsi ...	1	Adult	F	96	25	14	36	41	40	42	32	25
	5	,,	M	90	21	14	36	39	38	41	31	26
	6	,,	F	95	26	13·5	36	38	40	44	35	28
	7	,,	F	96	21	15·5	38	41	41	44	32	27
	8	,,	F	91	22	14	39	41	40	40	32	25
		AVER	AGE	93·6	23·0	14·2	37·0	40·0	39·8	42·2	32·4	26 2
H. brucei ...	2	Adult	M	86	22	11·5	32	40	33	38	32	26
	4	,,	M	85	21	12·0	32	37	32	39	31	25
	3	Immature	F	71	17	10 0	27	32	—	37	30	25
P. transvaalensis ...	F.D.A. 6	Adult	?	115 ?	32	19	43	50 ?	46	46	38 ?	29 ?
"*Hyrax*" sp.	T M, 1223	Adult	M ?	78	18	13	32 ?	34 ?	—	40 ?	31 ?	25 ?

The skull of *P. transvaalensis* in all its dimensions exceeds the maximum values obtained for *P. capensis coombsi*. It appears to have a relatively large facial skeleton and a short, broad cranium. The other fossil stands in marked contrast to *P. transvaalensis*, the measurements of the skull being less than those of the adult male *H. brucei*. There is no conspicuous difference in proportions between this fossil and the recent forms.

On account of the incomplete state of the fossil casts, comparison of the dimensions of the endocranial cast has been limited to three measurements of the cerebrum, viz., its length from the root of the olfactory bulb to the posterior extremity, its maximum breadth and maximum height. Table I shows that in *P. capensis coombsi* these measurements have a range of variation of approximately 10 per cent., there being general but not exact agreement between the size of the cerebrum and that of the skull; the cerebrum of *H. brucei* is slightly smaller than that of *P. capensis coombsi*.

In the case of *P. transvaalensis*, while the length of the cerebrum can be accurately measured, the breadth has to be inferred from that of the right hemisphere. The height also can only be determined approximately, since the lower border of the

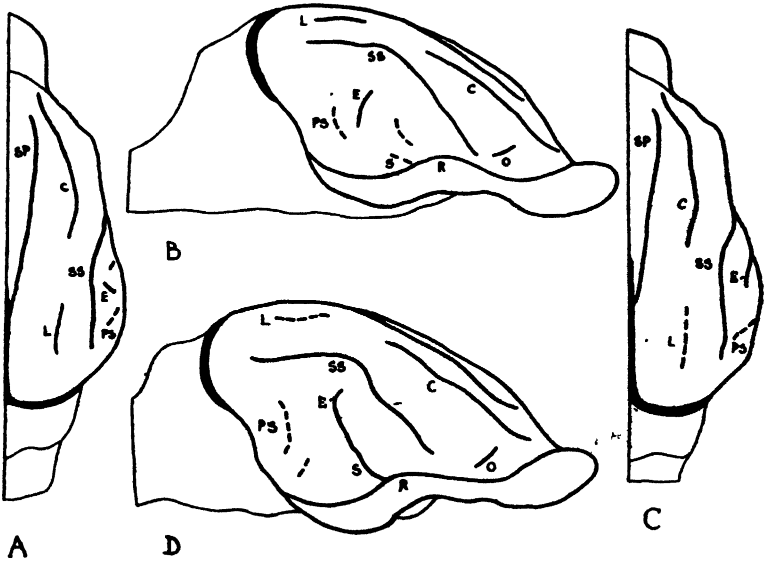

Fig. 1.—Dioptographic tracings of endocranial casts of *P. capensis coombsi*, showing interpretation of sulcal impressions based on comparison with the corresponding brains. Well-marked sulci in continuous line, indefinite in interrupted line, venous sinuses in solid black. Sp, splenial; C, coronal; L, lateral; SS, supra-sylvian; O, orbital (pre-sylvian); S, pseudo-sylvian; E, "ecto-sylvian"; PS, post-sylvian; R, rhinal. Natural size.

right hemisphere is not exposed. The value given in the table is the largest estimate possible. It will be seen that all these measurements, while they exceed those of *P. capensis coombsi*, do so to a considerably less extent than do the measurements of the respective skulls. Thus the cerebrum is smaller relative to the skull in *P. transvaalensis* than in the recent types. In the case of the smaller fossil, the dimensions of the cerebrum can only be very approximately estimated. From the portion which is exposed, however, it appears that the cerebrum in this type was at least equal in size to that of *H. brucei*.

Fig. 1 shows the range of variation in the contour of the endocranial cast of *P. capensis coombsi*. In one specimen (Fig. 1, A.B.) the cerebrum is elongated, with a tapering anterior extremity. A second cast (Fig. 1, C.D.) is relatively broader and more truncated anteriorly; the temporal region is also fuller in this specimen. In *H. brucei* the endocranial cast tends to be relatively broader than in *P. capensis coombsi*, but its frontal region is of the more tapering form. *P. transvaalensis* also has a relatively broad cerebrum, the anterior extremity of which is truncated, with a prominent antero-lateral angle (Fig. 2, A). The contour of the smaller fossil cast, so far as it can be determined, reveals no distinctive features.

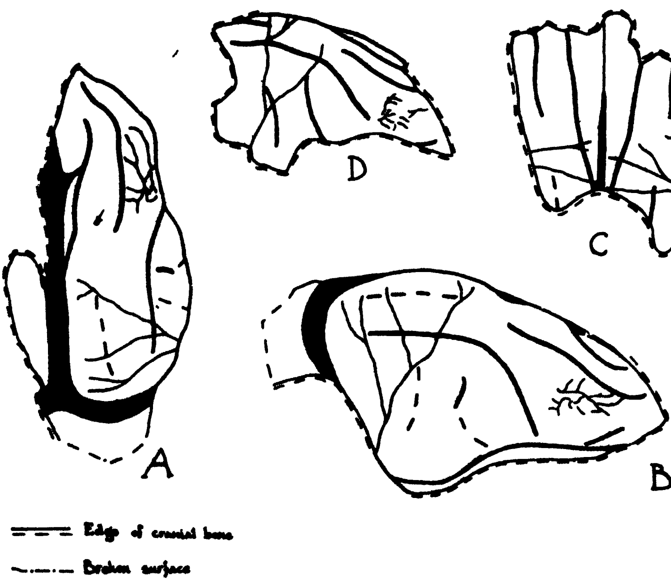

Fig. 2.—Dioptographic tracings of fossil endocranial casts (A, B, *P. transvaalensis*, C, D, "*Hyrax*" sp.), showing interpretation of the sulcal impressions in the light of recent specimens. Meningeal vessels in thin continuous line, venous sinuses in solid black. Natural size.

2. *Vascular Impressions.*

The impressions of the middle meningeal vessels are more or less sharply defined in all the casts. Their main features are essentially the same in both the recent and the fossil types (Fig. 2). Appearing on the lateral aspect of the cerebrum near the posterior extremity of the rhinal fissure, the artery divides into three principal branches, whose minor ramifications cover the posterior half of the surface of the cerebrum.

In both the fossil casts small, irregularly disposed impressions of anterior meningeal vessels are visible in the region of the antero-lateral angle of the cerebrum. It has been possible to demonstrate these fine impressions in only one of the eight casts taken from recent skulls. This emphasises the fineness of the detail revealed by these naturally formed casts, which it is extremely difficult to equal in artificially prepared specimens, at least when these are made from newly macerated skulls.

The position of the superior sagittal venous sinus is marked in the endocranial casts of recent Hyraces and in Dr. Broom's specimen by a slender ridge in the posterior half or third of the cerebrum (Fig. 1, A.C., 2, C). This ridge in recent Hyraces divides posteriorly into those marking the position of the transverse sinuses, which follow the posterior border of the cerebrum in its dorsal half. In the case of *P. transvaalensis* (Fig. 2 A), however, the calibre of the sagittal sinus is relatively much greater than in any of the other specimens. Moreover, the ridge marking its position can be traced in at least the posterior four-fifths of the cerebrum. At the junction of the anterior and middle thirds of the cerebrum this sinus is joined by the impression of a superficial cerebral vein issuing from the splenial sulcus. Posteriorly the ridge of the sagittal sinus is continued into the equally conspicuous impressions of the transverse sinuses.

3. *Convolutional Pattern.*

The sulcal pattern of the recent Hyraces has been described by Elliot Smith (1902), who in this and a subsequent publication (1903) has remarked upon its variability in certain respects. In the series of brains of *P. capensis coombsi* examined, the full range of variation described by Elliot Smith is represented.

One of the most constant sulci in this group is the splenial or intercalary sulcus, which has an unusual situation on the superior surface of the cerebrum. Commencing just behind the anterior extremity of the cerebrum, it runs backwards and slightly medially to the occipital pole, where it disappears on to the postero-medial surface. In the endocranial cast (Fig. 1 A.C.) the impression of this sulcus is only traceable in the anterior two-thirds of the cerebrum, its posterior end merging with the grooves flanking the ridge of the sagittal sinus. This impression in "*Hyrax*" sp. (Fig. 2 C) remains distinct until it disappears under the anterior edge of the interparietal bone. On the other hand, in *P. transvaalensis* (Fig. 2 A) it cannot be followed beyond the mid-point of the cerebrum; this may be ascribed to the

masking of the posterior portion of the sulcus by the very large sagittal sinus of this fossil.

The coronal sulcus, which runs parallel to the anterior portion of the splenial, is constantly developed in the brains of the recent Hyraces, and its impression is equally conspicuous in the casts of the recent and the fossil types. In the posterior part of the cerebrum, the line of the coronal sulcus is continued by the lateral sulcus. Indeed, in some casts of *P. capensis coombsi* and in the smaller fossil cast, the impressions of these sulci appear as deeper portions of a longitudinal depression extending the whole length of the hemisphere A small separate tri-radiate indentation is sometimes found in the interval between these sulci, as in a specimen figured by Elliot Smith. It may, however, be merged with the posterior end of the coronal sulcus, which appears to be the case in both the fossil casts examined. Both the recent and the fossil specimens display a transverse groove or constriction in the interval between the coronal and lateral sulci, which is not due to any feature of the brain.

As was pointed out by Elliot Smith, the lateral sulcus is much less constant than the coronal. In several specimens of *P. capensis coombsi* (Fig 1 C) and all these of *H. brucei*, it is represented not by a true sulcus, but by a shallow depression. This depression, however, produces a ridge on the internal aspect of the skull, and is therefore represented on the endocranial cast by an indentation, which, had the casts not been compared with the corresponding brains, might have been taken for the imprint of a true sulcus. The impression of a genuine lateral sulcus is, however, much more strongly marked than that of such a pseudo-sulcus. This feature is very diversely developed in the two fossil casts. In *P. transvaalensis* it is represented by a depression so shallow and ill-defined that the absence of a true sulcus may safely be inferred. Only the anterior half of the depression is exposed in the other fossil, but this is so deep and sharply defined that the presence of a true lateral sulcus is incontestible.

The arched supra-sylvian sulcus produces a most conspicuous impression in the casts of both recent and fossil types. Its posterior portion is horizontal, while the anterior extremity descends steeply to approach, but not join, the upward convexity of the equally conspicuous sigmoid rhinal fissure. The orbital or presylvian sulcus is consistently well developed in *P. capensis coombsi*, but in *H. brucei* it is less definite; its impression is sharply defined in both the fossil types.

In *P. capensis coombsi* the sulci of the region enclosed by the supra-sylvian sulcus display the full range of variation described by Elliot Smith. Fig. 1 B illustrates the one extreme, in which the pseudo-sylvian (feline sylvian) sulcus is represented only by a short indistinct groove ascending from the rhinal fissure. Above this is a small, deeply indented sulcus, which occupies the position of that tentatively labelled "post-sylvian" in Elliot Smith's figure of *P. capensis*. That name, however, seems rather

to belong to the less sharply defined sulcus placed posterior to this; the more conspicuous indentation may provisionally be termed " ecto-sylvian." In a more advanced stage the pseudo-sylvian becomes a deep, though short, sulcus, notching the upper edge of the rhinal fissure, and linked by a shallow groove with the deeply indented " ecto-sylvian " sulcus. Finally, as in Fig. 1 D, a continuous deep furrow represents the confluent pseudo-sylvian and " ecto-sylvian " sulci. In these specimens the post-sylvian sulcus also becomes more extensive and better defined. As shown in the figures, inconspicuous and inconstant minor indentations may also be present. The brains of *H. brucei* conform to the simplest of the arrangements seen in *P. capensis coombsi*, the pseudo-sylvian sulcus being only slightly indicated; there is a small, sharply defined " ecto-sylvian " and a much less definite post-sylvian sulcus.

Without reference to the actual brains the impressions of these sulci upon the endocranial cast might easily have been misinterpreted. Even an incipient pseudo-sylvian sulcus is represented on the cast by a shallow groove, which tends to become confluent with the deeper impression of the " ecto-sylvian " sulcus, producing the illusion of a long continuous sulcus. As the pseudo-sylvian sulcus increases in definition, its impression upon the cast becomes sharper. When the psuedo-sylvian and " ecto-sylvian " sulci are fully confluent, they are represented on the endocranial cast by an impression as strongly marked as that of the supra-sylvian sulcus. The post-sylvian sulcus is only indistinctly indicated on the cast.

The two fossil casts reveal a striking divergence in the features of this region. In *P. transvaalensis* the position of the pseudo-sylvian sulcus is marked by a broad shallow crescentic impression which becomes deeper in its upper portion. Comparison with recent specimens suggests that the pseudo-sylvian sulcus was merely incipient, and that a separate, better-defined " ecto-sylvian " sulcus was present. As in the recent casts, the impression of the post-sylvian sulcus is indistinct. The smaller fossil, on the other hand, shows a deep continuous groove indicating complete confluence of the pseudo-sylvian and " ecto-sylvian " sulci. This cast is further remarkable for the sharpness of the impression of the post-sylvian sulcus, which rivals the sylvian complex in definition.

Discussion.

This study has once again emphasised the importance, in studies of the endocranial cast, of constant reference to the features of the actual brain. Even in forms with so simple and clearly defined a convolutional pattern as the Hyraces, it has been found that without a knowledge of the brain several features of the endocranial cast could easily be misinterpreted.

The recent Hyraces reveal a constancy in the general form of the endocranial cast and in many of its surface features. In these points, the fossil casts examined also correspond with those

of the recent types. These unvarying features may be taken as characteristic of the brain in the Procaviidae. On the other hand, both in the absolute size of the cast and in certain details of its structure there is a considerable range of variation, both within the limits of the single group *P. capensis coombsi*, and between this group and *H. brucei*. It is principally in these features which are inconstant in the recent types that appreciable differences are shown by the fossil specimens. The only notable exception to this rule is the exaggerated prominence of the sagittal sinus impression in the *P. transvaalensis* cast, the significance of which cannot as yet be determined.

Apart from this, the first distinctive feature of the endocranial cast of *P. transvaalensis* is its absolute size. That it should exceed the maximum attained in *P. capensis coombsi* is to be anticipated in view of the much larger size of the skull. It has been shown, however, that relative to the skull as a whole the brain was not so large in *P. transvaalensis* as in *P. capensis coombsi*. This by itself does not imply a lower level of cerebral development in the fossil than in the recent type. In the brains of closely related types of different size " the linear dimensions . . . increase much less than the linear dimensions of the whole body, viz., proportional to their 5/9th power only instead of the first power " (Bok and v. Erp Taalman Kip, 1939). Thus the relative size of the brain becomes progressively less as the bulk of the body increases. It is very probable that this effect largely accounts for the relatively smaller brain of *P. transvaalensis*.

A more significant feature of this specimen is the relative simplicity of the inferred convolutional pattern. The complexity of the convolutional pattern is known to increase with increasing volume of brain, because the surface area of the cortex increases at a greater rate than the linear dimensions of the cerebrum (Bok and v. Erp Taalman Kip, 1939). That this effect is not limited to very large differences in size, but can be appreciated even in variations of the order found in the Procaviidae, is suggested by the comparison of the average convolutional complexity in *P. capensis coombsi* and *H. brucei*. Thus it might have been anticipated that the cast of *P. transvaalensis* would have rivalled the most complex specimen of *P. capensis coombsi*, whereas it corresponds with the simpler examples of that type. Even if the range of variation in *P. transvaalensis* equalled that found in *P. capensis coombsi*, it seems that the average complexity of the brain was not greater in the former than in the latter species, despite the difference in size. This feature, much more than the relatively smaller size of the endocranial cast, suggests that *P. transvaalensis* fell short of the recent Hyraces in cerebral development.

The smaller fossil endocranial cast offers a striking contrast in this respect. Not only is the relative cerebral volume probably as great in this specimen as in the recent types, but the convolu-

tional pattern is elaborated to a degree at least as great as has been observed in any Procaviid. Thus even if this cast represents the extreme of cerebral development in this species, it suggests an average degree of complexity comparable with that seen in *P. capensis coombsi*.

It is conceivable that the slightly inferior cerebral development of which evidence has been found in *P. transvaalensis* may have sufficed to determine the extinction of this species, especially under conditions of climatic stress such as are now known to have characterised parts of the Pleistocene period. The other contemporary fossil type, however, appears, so far as cerebral development is concerned, to have been as well equipped for survival as the existing species. On the basis of this character alone, one would be tempted to speculate that this fossil type ("*Hyrax*" sp.) might have been directly ancestral to some of the modern Hyraces. It is, therefore, of especial interest that Dr. Broom finds a very close resemblance in many respects between this fossil and living forms.

SUMMARY.

A description has been given of two natural endocranial casts of Pleistocene Hyraces, one belonging to *Procavia transvaalensis* Shaw, the other to a smaller, unnamed type discovered by Broom. These have been compared with brains and endocranial casts of the recent forms *P. capensis coombsi* and *Heterohyrax brucei*. The fossil casts correspond with recent specimens in their general form and many details. They reveal, however, differences in absolute size and in certain structural features, principally those which are variable in the existing types. The possible bearing of these differences on the relation between the fossil types and recent species are discussed.

I have to record my thanks to Professor J. C. Middleton Shaw and to Dr. Robert Broom for the loan of the fossils described in this paper, and to Dr. Austin Roberts for the identification of the recent specimens examined.

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A NOTE ON THE HABITS, LIFE HISTORY AND DISTRIBUTION OF *OEDURA HALLI*, Hewitt

BY

J. H. Power,

Principal, Griqualand West Technical Institute.

Read 4 July, 1939.

During a collecting excursion into the interior of Basutoland in December, 1938, four adult specimens of this gecko, together with several eggs were secured.

The country in the neighbourhood of Roma Mission Station where I made my headquarters consists of deep, narrow valleys between flat-topped hills. These hills slope gently until near the top when they rise sheer for sometimes 200 feet. The slopes are covered with grass and shrubs, while the flat tops are grassy; the precipitous sides are smooth bare sandstone.

Habitat.

In places the soil has been washed away for eight or ten yards from the precipitous edges of the hill tops leaving the bare rock exposed. It was at such places that the geckos were found. They are apparently fairly common in the neighbourhood of Roma judging by the number of pairs of eggs observed, but owing to the secretiveness and nocturnal habits only four specimens were secured.

Habits.

They hide during the day in the deep recesses of narrow clefts in the rock, coming out at night to hunt for their prey.

The food consists entirely of insects. The stomachs of those examined contained fragments of various insects, principally ants and small beetles.

Life History.

At the same places where the adults were found several batches of eggs were secured. These, without exception, were found under loose more or less flat stones lying on the top of the bare rock.

The eggs are oval in shape and have a thin calcareous shell which is very brittle. Twenty-three eggs collected varied in size between 16 x 12 mm. and 12·5 x 10·0 mm., the average being 14·5 x 10·9 mm. across the major and minor axes respectively.

When laid they are apparently covered with an adhesive substance which causes them to stick to the rock and to each other. In most cases they adhered so firmly that the portion of rock to which they were attached had to be chipped off with a hammer and chisel. Unfortunately, in the process many eggs were destroyed. The colour is white, but in the case of newly-laid eggs they are pinkish, due to the underlying vascular membranes.

When first laid the calcareous shell is evidently quite soft for, in every case, the portion adhering to the rock took the shape of the rock surface; in many cases being perfectly flat.

Evidently two eggs are laid at a time, as in every case they were found adhering together in pairs, and in the case of one gravid female secured there was a fully developed egg in each oviduct. Several females apparently lay their eggs in the same place as, in many instances, two or three pairs of eggs were found under the same stone; in one case as many as five pairs were found together. It appears from this that the sight of previously laid eggs stimulates gravid females.

In a few cases eggs were found under stones that had no eggs beneath them the previous day; these were marked in order to ascertain the period of incubation.

In these new-laid eggs the embryo was found to be in a fairly advanced stage.

From eggs laid on the night of December 8th the young hatched out on January 16th; another pair laid on December 10th hatched on January 19th. This indicates an incubation period of between five and six weeks. It must be remembered, however, that the eggs were kept in a box, indoors, during the above periods; if they had been in their native place beneath stones heated by the sun's rays during the day, no doubt they would have hatched sooner.

When the embryo is fully developed within the egg it lies coiled upon itself so that the head is brought forward until the tip of the snout touches the base of the tail. The tail is bent round until the tip reaches the root of the forelimb. The hind feet are beneath the head, while the forefeet lie on either side of the body near the base of the hind limbs.

According to Smith (1935) the embryos of oviparous lizards are provided with a sharp calcareous egg-tooth at the extreme tip of the snout, to enable them to escape from the eggs; he further states that in the case of geckos the tooth is double.

Fully developed embryos of *Ocdura halli*, examined by me, show no such tooth. When leaving the egg the young do not cut out a neat circular opening at the end. Of twenty young which hatched out of the collected eggs, each one made a jagged tear in the shell. Moreover, the shell was broken either at the end or at the side.

The newly hatched geckos averaged 22·5 mm. from snout to vent, tail 19·5 mm. The adults measure 62·5 mm. from snout to vent, tail 65·5 mm.

Colour.

The dorsal surface of the newly hatched young is a light grey with light brown transverse bands; the whole surface speckled with minute white spots. With age the dark transverse bands break up into irregular blotches.

In adult life there is considerable variation in the intensity of the ground colour, which may vary from grey to brown.

Distribution.

The type of this species was described (Hewitt, 1935: 321) from specimens collected at Telle Junction, near Palmietfontein, Herschel District, C.P., at a height of about 4,500 feet. It has also been previously recorded from Herschel, and Cala, Xlanga District, C.P.

It is a mountain-loving species, but has a rather restricted distribution, being apparently confined to the southern Drakenberg, the Malutis, and the Stormberg.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVI, pp. 377-380, December, 1939.*

THE STATUS OF *MABUYA OCCIDENTALIS*, Peters

BY

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Read 4 July, 1939.

For a considerable time I have had doubts as to the systematic position of *Mabuya occidentalis.* These were recently strengthened in the course of a review of the reptiles and amphibians of Griqualand West, in which it was intended to embody the subject matter of this paper. As the work on this review is now suspended indefinitely, it seemed advisable to place them on record.

The present paper concerns only the material in the Kimberley Museum collection, which consists of 55 specimens, some of which are juvenile. While most of the collection was made in Griqualand West, and the south-west portion of Gordonia, it contains interesting specimens from other parts of South Africa.

What follows is an attempt to show that *M. occidentalis* and *M. trivittata* merge into each other and consequently cannot be retained as distinct species. Unfortunately the series at my disposal was not as large as I should have wished, but it consisted of material from the most interesting localities.

Distribution.—In 1912 (Hewitt and Power, 1913: 158) it was thought that these two forms were sharply separated geographically. Since then, however, the author has done extensive field work and broadened the range of *M. occidentalis* considerably.

It was previously known from Hereroland, Damaraland and a couple of places in the Cape Province. It is now known to occur at several places in Western Gordonia, while the author has collected it at Postmasburg, Niekerk's Hoop, Prieska, Marydale, Draghonder, Kenhardt, Upington, De Aar, and at Witput Siding, near Belmont, C.P. Nevertheless, the Western Kalahari seems to be its particular area.

On the other hand *M. trivittata* has an extensive distribution, occurring from east to west coasts and from the Limpopo River to the Cape Peninsula.

Then, again, *trivittata* is apparently absent from certain areas where *occidentalis* is plentiful. During a trip through Western Gordonia, made by Miss Wilman, Curator of the Kimberley Museum, in 1912, several specimens of the latter were

secured, but none of the former. I was surprised, also, to note that not a single specimen of *occidentalis* was found during the Transvaal Museum Expedition to S.-W. Africa (FitzSimons, 1938: 200-203) notwithstanding that the type came from Damaraland.

Specific Characters.—Characters used to separate *occidentalis* from *trivittata* are the differentiation of the anterior ear-scales, the degree of keeling of the subdigital scales, and the degree of carination of the dorsal scales. After a critical examination of the above characters, and comparison of them with those of *trivittata*, I am convinced that the differences are not constant. They are applicable to say, *trivittata* from Kimberley and *occidentalis* from Gordonia, but difficulties arise with material from a place like Niekerk's Hoop, where both forms occur.

The degree of keeling of the subdigital scales varies considerably; some specimens of *occidentalis* from Ky Ky, W. Gordonia possess strongly keeled subdigital scales while others from much further east, in the area occupied by *trivittata*, have these scales only feebly keeled. There is also considerable variation in the anterior ear-scales, so much so, in fact, as to have specimens of *trivittata* taken as *occidentalis* and vice versa.

It is unnecessary to give a detailed account of all the doubtful specimens examined; the following are a few of the more striking ones: A specimen from Witput Siding has the dorsal colouring an olive brown with the usual three dorsal stripes, but with no transverse bars of black. The subdigital scales are not strongly keeled and the anterior ear-scales only slightly differentiated. The dorsal scales are strongly tricarinate.

One specimen from Postmasburg, which I identified as *trivittata*, is light brown above with three dorsal stripes and faint lateral stripes with transverse brown spots; the subdigital scales are strongly keeled, but with no differentiated ear-scales.

Another speciment from the same place is a dark brown dorsally, with three very bright dorsal stripes and lateral stripes bordered with black, but no transverse markings. This specimen has two of the anterior ear-scales distinctly larger than the others; the subdigital and dorsal scaling is, however, no different from that in typical *trivittata*.

A series of five specimens from Niekerk's Hoop show a complete gradation in the differentiation of the anterior ear-scales, from typical *trivittata* to typical *occidentalis*.

One from Mud River, Malmesbury, with a colouring as in typical *trivittata* has one anterior ear-scale slightly differentiated, toes subdigital, scales strongly keeled, dorsal scales strongly keeled.

A juvenile from De Aar shows hardly any difference in the anterior ear-scales, although the colouring is of typical *occidentalis*.

The most distinctive individuals in every respect, including colour, were those collected at Upington.

Boulenger (1887: 196-197) says " Ear opening with two or three large, obtusely pointed projecting lobules anteriorly." In no case were there three enlarged ear-scales, and in seven cases there was only one such scale in the specimens examined by me.

The degree of carination of the dorsal scaling varies so slightly from that of *trivittata*, that it is quite useless as a distinguishing character.

The following percentages of the specimens examined give one a better idea of the facts:—4 per cent. have the subdigital scales feebly keeled; 13 per cent. have dorsal scales feebly keeled; 7 per cent. have only one differentiated anterior ear-scale; 91 per cent. have two differentiated anterior ear-scales; 60 per cent. have the anterior ear-scales only slightly enlarged; 7 per cent. showed no enlarged ear-scales.

Three specimens of otherwise typical *trivittata* have one enlarged anterior ear-scale.

Colour.—The colour varies considerably and depends, more or less, on habitat conditions. Dorsally it may be dark brown, chestnut-red, or dull yellow, with many intermediate stages. There are three dorsal and one lateral stripe, which vary from being very indistinct to being most striking. The indistinct stripes are mostly found on specimens of a general dull yellow colour, from the Western Kalahari, while the white stripes, bordered with black, are found on those whose general dorsal colour is dark brown. These latter specimens come from Niekerk's Hoop where they were found, together with typical *trivittata*, in thick undergrowth. Individuals collected at Upington, in loose scrub growing on red sand, are a chestnut-red dorsally with distinct dorsal and lateral stripes.

During the examination of the specimens at my disposal certain features stand out as possibly being adaptation. They are as follows:—

(a) The length of the toes and the amount of keeling of the subdigital scales in specimens from the Western Kalahari is greater as compared with those from Niekerk's Hoop and Witput Siding.

(b) The length of the enlarged anterior ear-scales is much greater in specimens from Western Gordonia than those from Niekerk's Hoop or Witput Siding.

(c) The colour of those from the Western Kalahari is pale dull yellow with faint stripes, while those from further east, at the above mentioned places are dark brown with very distinct dorsal and lateral stripes.

The longer toes, more carinate subdigital scales, larger ear-scales, and pale colouring, may be produced by desert or semi-desert conditions.

Relationship of the Species.—That the two forms are very closely allied is certain; all the evidence at hand seems to indicate that *occidentalis* is derived directly from *trivittata*.

The general criterion adopted by systematists in the discrimination between species, is constancy in the characters used to separate them. This criterion when used for the extremes of the two forms certainly places them as distinct species. When, however, as has been shown, there is evidence of a significant degree of morphological overlap between the two forms, at a point of geographical contact between them, it is generally accepted that the more recent form should be relegated to sub-specific rank. Hence I propose that *Mabuya occidentalis* should be regarded as a sub-species of *Mabuya trivittata*.

The author's thanks are here tendered to the National Research Council for financial aid in the field work necessary to secure valuable material.

Summary.

1. In the course of this study attention has been directed entirely to the characters used by systematists as diagnostic of the species. It has been interesting to find that these characters are unstable and therefore cannot be used for diagnostic purposes.

2. No constant characters exist to distinguish *M. occidentalis* from *M. trivittata*.

3. It is suggested that *M. occidentalis* be relegated to sub-specific rank, although the extremes of the two forms are distinguishable on external characters.

4. The difference between them may be attributed to a difference in habitat.

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A NOTE ON QUANTITATIVE METHODS IN THE OBSERVATION OF BIG GAME IN THE KRUGER NATIONAL PARK

BY

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Read 4 July, 1939.

1. INTRODUCTION.

The animals in the Kruger National Park provide the student of animal population dynamics with an extraordinarily interesting and unique field. Living as they do almost free from the fear of man and in their natural surroundings, they present us with an opportunity of seeing them as they were accustomed to live before man came on the scene. Motor cars are objects of curiosity and unassociated within the confines of the park with fear of man. The animals' only contact with man as a hunter is when they leave the area of the park to seek food and water at times of scarcity. But this happens normally in winter and not in summer when they are breeding, so that in essentials the park remains their natural home.

The approach to naturalness of conditions for the animals in the park was pushed a step further when control of carnivorous animals was abandoned, once the much diminished ungulate population had been given time to regain something like its normal status. Experience has shown that the interaction of carnivore and herbivore has resulted not, as some would have it, in the extermination or driving away of the most usually preyed upon animals, but in an apparent regulation of the numbers of carnivores to their available food supply.

In the years during which herbivorous animals were to some extent protected by reducing the number of lions, wild dogs, leopards and others, fluctuations in their numbers occurred which seem to have been largely independent of the predator factor, being brought about by climatic influences on the amount of food available and by disease; in addition it is probable that there was competition among them for available habitats, consequent upon increased density, and this would contribute to changes in numbers in the area.

Hitherto wild animals have been studied more as to their individual natural history than as units in a population. Notable exceptions are the insight and knowledge of the animals in the Kruger Park that have been obtained by the Warden, Col. Stevenson-Hamilton and his staff during the 37 years of protec-

tion and the pioneer work of the Tsetse Research Department in Tanganyika, under the direction of the late Col. C. F. M. Swynnerton. The large amount of information that has been gathered by expeditions, game wardens, hunters and others provides the basis for more detailed quantitative studies of African big game.

We have now reached a point where it is imperative, if our precious fauna is to be preserved for posterity, to work up the knowledge which we possess into a picture with, supplemented and given added meaning by modern methods of population research, will show the interrelations of the different animals, predator and prey, with each other and with the environment in which they live. This will enable us to replace the generalised picture that, up to now has been obtained from long and intimate knowledge and experience, by facts and figures which, illustrating as they do the same phenomena, give the picture the added quality of statistical accuracy. We shall then be able to sum up the position with fewer reservations and to forecast with some confidence the future trends and requirements of the animals, so necessary for scientific management.

2. Animal Population Theory.

The growth of animal populations, whether they be of fruit flies, mice or men, follows the same general plan and the same kinds of data are needed for its study. Animals have theoretically enormous powers of increase. The natural rate of reproduction is offset, in the main, by limiting factors in the environment such as climate, food supply, disease, accidents, enemies, etc. These factors, throughout the growth of the population, take a greater and greater toll the nearer the population reaches saturation point. The saturation point is determined by two chief factors. The available space (i.e. the extent of habitat in which the animal is adapted to live) and the suppply of food. Once the food supply in the particular habitat is reduced below a point where it can maintain the animals, something happens. It is sometimes death through epidemic disease, and sometimes mass migration (cf. springboks migrating west to the sea and lemmings in Norway migrating periodically from their mountain habitat).

In carrying out quantitative work on animal populations, methods of census are of first importance. Good census figures provide us with the actual rate of increase and numerical status of the populations under investigation. In practice it is not always possible to make total counts, so the rise and fall in numbers is followed by sampling methods which show the relative changes in numbers at set periods. At the same time as census observations are taken investigation is made of the reproductive state and age structure of the population on which to build up statistics of the potential rate of increase, to compare with the actual rates found by census. An attempt is also made to estimate the extent to which the different factors, disease, accidents,

enemies, food shortage—contribute to the sum of mortality. The other side of the work lies in determining the animals' habitat, its relation to other animals, climate, etc.

3. OBSERVATIONS ON THE ANIMAL POPULATION OF THE PARK.

I propose here to give some idea of a few observations on the distribution and numbers of certain animals as shown in records taken from a car on visits to the reserve. The observations are of little value as contributions to the great problem of the game population in the reserve, but they serve the purpose of showing that there are possibilities in the general methods that have been tried out in this preliminary and experimental way.

(a) *Conditions of Observation.*—The observer is limited to the 1,200 miles of road that now open up the 8,000 square miles of the park. His observations can only be made in daylight. He is confined to his car and the distance at which he can see animals is determined both by the weather and the type of country and vegetation. On the average the effective visibility is often not more than 50 yards to each side of the road, only in exceptionally open country is it more than 200 yards. The roads themselves fall into two groups: (i) Trunk roads joining key points and (ii) what we may call game roads, which open up areas where game is either numerous or particularly interesting. Roughly the mileage of the two is the same. Further classification can only be done with a knowledge of the vegetation and of the types that go to make up the habitats of the different animals and of the seasonal distribution of water and grazing.

(b) *Factors Affecting the Game in Observation.*—Under different conditions of weather, at different seasons and at different times of the day the animals will behave in a different way. Also different types of country offer different facilities for seeing animals from the road. All these factors must be considered and assessed in observations made under park conditions. The daily movements seem to be most important and a knowledge of an animal's daily activities in relation to drinking, feeding and resting is essential. In addition must be mentioned the attraction or otherwise roads and motor cars have for animals and the game's increasing tameness.

(c) *Factors Affecting the Observers in Observation.*—At least two people must be observing at the same time. The more the better. The chief factors that affect the observer are the amount of cover and visibility and his own qualities as an observer. His observations will depend on keen sight and quick counting and estimating and a knowledge of the characteristic points about animals which reveal their age and sex—most important points in recording the age and sex structure of herds. Further, some knowledge of the vegetation and food plants is necessary.

(d) *Method of Observation.*—The counts were made by two persons from a car travelling at between 10 and 15 m.p.h. When

animals were numerous or partially hidden, a conservative estimate of their numbers was made. Notes on prominent features, rivers, pans, boreholes, etc., and type of vegetation, time of day and weather were kept. The number of animals seen was recorded to 1-10th of a mile. A later refinement was to estimate the distance of the animals from the road.

A suggestion for game reconnaissance, similar to the one tried out here, was made by the late Col. G. F. M. Swynnerton, where he says " It may be remarked here that the recording of game density in Africa has hitherto been very unsatisfactory " and goes on to say that vague terms such as " abundant," " scarce," etc., are of almost no value as they are subjective and vary with each individual. Col. Stevenson-Hamilton tells me that before the Great War one of his rangers was beginning similar observations in an attempt to estimate density, so the idea is not new.

(e) *Some of the Results.*—Counts have been made on three visits: at the end of August and beginning of November, 1938, and at the beginning of May, 1939. In all, 8,300 animals of all species have been recorded over a distance of 820 miles. Part of this mileage was over the same ground. For the purpose of illustration I have selected a journey from Skukuza to Punda Maria done in August, and a series of four journeys between Pretorius Kop Camp and Skukuza done in May.

Only the six most frequently seen herbivores are given, namely, in order of frequency: Impala (*Aepyceros melampus* Licht.) Blue Wildebeeste (*Gorgon taurinus* Burchell), Burchell's Zebra (*Equus quagga* Gmel.), Greater Kudu (*Strepsiceros strepsiceros* Pall.), Common Waterbuck (*Kobus ellipsiprymnus* Ogilvy) and giraffe (*Giraffa camelopardalis* L.).

The number of animals seen is shown in Tables 1 and 2 for the two journeys. Each individual or group of animals is given separately as the number seen in five mile intervals.

(i) *Skukuza to Punda Maria.*—Between Skukuza and Punda Maria the highest concentration of game was seen in the Skukuza area, particularly in the vicinity of Tschokwane. Then going north, impala were practically the only representatives until past the Olifants River, when in the neighbourhood of Shingwedzi the other species with the exception of giraffe reappeared, wildebeeste, however, only being found in very small numbers near Punda Maria. This route covers the length of the Park, and represents a sample cross-section of the reserve, which includes the two characteristic types of vegetation—the thorn country to the south and the mopani bush to the north of the Olifants River.

This " strip transect " through the length of the Park gives a cross-section of the population at a time when food and water supplies are at their lowest, i.e., at the end of winter and before the rains. A similar journey in summer has not been done.

TABLE I—ANIMALS SEEN BETWEEN SKUKUZA AND PUNDA MARIA IN AUGUST, 1938.

Miles.	Impala.	Wildebeeste.	Zebra.	Kudu.	Waterbuck.	Giraffe.	Total.	Miles.	Route.
0-5	100	—	—	—	—	—	100	0-5	Skukuza, Sand R.
6-10	13	—	—	2	5	—	20	6-10	Metulimbi R.
11-15	8-1	1-1	—	2	—	—	13	11-15	Manzemdlovu R.
16-20	30-6-1-1-1	1-1	1	3	—	9	74	16-20	Lion Pan.
20-25	40-7	3-1	50-5-4-3	7	3-1	9	133	20-25	Tschokwane, Manzemntando R.
26-30	5-1-1-1	50-40-20-20-8 7-7-6-1-1	50-12-10	4	—	—	244	26-30	
31-35	—	—	—	1	—	—	1	31-35	
36-40	1	—	—	1	—	—	2	36-40	
41-45	—	—	—	—	—	—	—	41-45	
45-50	—	3	—	—	—	—	3	46-50	
51-55	2	-	—	—	9	—	11	51-55	Satara.
56-60	6-3	—	—	—	—	1	10	56-60	
61-65	3	—	—	—	—	3	6	61-65	Mabumbey R.
66-70	50	—	—	—	—	—	50	66-70	
71-75	30	—	—	—	—	—	30	71-75	
76-80	12	--	—	—	—	—	12	76-80	
81-85	—	—	—	—	—	—	—	81-85	
86-90	—	—	—	—	--	—	—	86-90	Olifants R.
91-95	2	--	—	—	—	—	2	91-95	
96-100	4	—	6-3	—	—	—	13	96-100	
101-105	1	—	--	—	--	--	1	101-105	
106-110	8-6	--	—	—	—	--	14	106-110	Letaba.
111-115	--	—	—	--	—	--	--	111-115	
116-120	--	—	—	—	—	—	--	116-120	
121-125	--	—	—	—	—	--	--	121-125	Groot Letaba R.
126-130	6-4	—	—	4	—	--	14	126-130	
131-135	--	—	—	—	—	—	—	131-135	
136-140	—	—	—	8-1	1	--	10	136-140	Shawo R.
141-145	—	—	5	—	2	—	7	141-145	
146-150	—	—	—	—	—	-	—	146-150	
151-155	1-1	—	—	10	8-8-3	-	31	151-155	
156-160	—	--	50	—	—	—	50	156-160	Shingwedzi.
161-165	30-6-2-2	--	1	6-2	5-3	--	57	161-165	
166-170	—	—	5	—	3	—	8	166-170	
171-175	—	—	—	—	—	—	—	171-175	
176-180	—	—	—	—	—	—	—	176-180	
181-185	9-6-2	1	—	2	7	—	27	181-185	
186-190	—	—	—	3-2	—	—	5	186-190	
191-195	—	—	—	—	—	—	—	191-195	
196-200	—	—	3	—	—	—	3	196-200	
201-205	—	—	—	—	—	—	—	201-205	Punda Maria.
—	433	172	208	58	58	22	951	—	

The occurrence of the six most frequently seen ungulates is shown in the table; each figure represents the number seen together at one time. The numbers in the larger herds were estimated, but counts were made when possible. Note the high concentration of game between Skukuza and Tschokwane and a secondary concentration in the Shingwedzi area.

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Table II—Animals seen between Pretorius Kop and Skukuza in May, 1939.

Miles.	Impala.	Wildebeeste.	Zebra.	Kudu.	Waterbuck.	Giraffe.	Total.	Miles.	Route.
0-5	—	12-12-6-3-3	—	2	—	—	38	0-5	Pretorius Kop (11.0 a.m.).
6-10	—	—	—	—	—	—	—	6-10	
11-15	1-1-1	20-15-14-1	3-2	3	—	—	61	11-15	Hippo. Pool Turn, Mlasha Spruit.
16-20	13-1-1-1-1-1	1	4	2	—	—	25	16-20	Sugela R.
21-25	24-20-20-8-3-1-1	8-4	11-5-5	2	—	—	112	21-25	
26-30	20-16-7-3-2-1-1-1	—	—	—	—	—	51	26-30	
31-33	5-2-2-2-2-1-1-1-1	—	—	—	—	—	17	31-33	Mutshidaka R., Skukuza (1.0 p.m.).
—	166	99	30	9	—	—	304	—	
0-5	—	11	3	—	—	—	14	0-5	Pretorius Kop (5.0 p.m.).
6-10	—	—	—	—	—	—	—	6-10	
11-15	25-2	17-1	4	—	—	—	49	11-15	Hippo. Pool Turn, Mlasha Spruit.
16-20	8-2-1-1-1	—	—	—	—	—	13	16-20	Sugela R.
21-25	27-20-13-7-6-4-3-3-3 1-1-1-1-1	7-5-1	8-2-2	—	—	—	116	21-25	
26-30	44-20-6-4-3-3-2-2-1-1-1-1	—	—	—	—	—	88	26-30	
31-33	4-4-4-3-2-1-1-1-1	—	—	—	—	—	21	31-33	Mutshidaka R., Skukuza (3.0 p.m.).
—	240	42	19	—	—	—	301	—	
0-5	—	18-4-2-1	4	8	—	—	37	0-5	Pretorius Kop (11.0 a.m.).
6-10	—	—	—	—	—	—	—	6-10	
11-15	50-20-10-1	14-8-8-2-1-1	—	—	—	—	115	11-15	Hippo. Pool Turn, Mlasha Spruit.
16-20	25-8-7-5-3-1-1-1-1	1-2	—	1-2	—	—	58	16-20	Sugela R.
21-25	40-5-1-1	1	1-3	—	—	—	52	21-25	
26-30	20-8-4-3-2-1-1-1	—	—	—	—	—	40	26-30	
31-33	16-15-9-5-3-1-1-1-1-1	—	—	—	—	—	53	31-33	Mutshidaka R., Skukuza (1.0 a.m.).
—	273	63	8	11	—	—	355	—	
0-5	—	4	10	—	—	—	14	0-5	Pretorius Kop (5.0 p.m.).
6-10	—	—	—	—	—	—	—	6-10	
11-15	1	16-12-6-1-1-1-1	8-6	—	—	—	53	11-15	Hippo. Pool Turn, Mlasha Spruit.
16-20	20-15-11-2-2-1-1-1-1-1	1	—	—	1	2	59	16-20	Sugela R.
21-25	36-23-11-11-10-4-1-1-1-1	4-1	4	—	—	—	108	21-26	
26-30	18-15-14-3-2-2-2-1-1-1	—	—	—	—	—	59	26-30	
31-33	20-8-2-2-2-1-1-1-1-1-1-1	—	—	—	—	—	41	31-33	Mutshidaka R., Skukuza (3.0 p.m.).
—	255	48	28	—	1	2	334	—	

The same animals as in Table I are given. Note the distribution of wildebeeste and impala. Impala appeared only when the open, park-like country round Pretorius Kop gave way to thicker thorn bush. The first two journeys were on the same day, and the second with an interval of two days between. The figures are arranged as if the journeys started at Pretorius Kop so as to facilitate comparison. The times indicate the direction.

To follow Table I.

(ii) *Pretorius Kop Camp to Skukuza.*—The figures in Table 2 are arranged as if all four journeys were made from Pretorius Kop, whereas they were two return journeys. The forward journeys were done between 11 a.m. and 1 p.m., and the return journeys were done between 3 p.m. and 5 p.m., the first two being on the same day and the second two with an interval of two days. The figures show the striking limit to the distribution of impala and the type of country preferred by wildebeeste at this time of the year. The open park-like country round Pretorius Kop was thickly populated with wildebeeste. Impala appeared only when the bush became thicker and changed in character. Comparing the returns for the four journeys, we find that the numbers of impala were 166, 240, 275 and 255; these for wildebeeste 99, 42, 63, 48; and for zebra 30, 19, 8 and 28. Kudu were seen only in the morning and giraffe and waterbuck but once only. These results raise important questions: is it in observation or in behaviour of the animals that we get this variation in numbers seen? What relation do these numbers bear to the total population of which these are a sample? Such questions can hardly be discussed, still less even tentatively answered and they must remain until much more has been done.

4.—Acknowledgments.

I am greatly indebted to Dr. J. McD. Troup for his collaboration in the exacting work of making and analysing the field counts. Without his interest and encouragement, these preliminary results would not have been brought to this stage. I wish to thank Col. Stevenson-Hamilton for the interest he has shown in this line of work and for many valuable suggestions.

5.—Summary.

The application of modern ideas and methods of population research to the big game population of the Kruger National Park may help to solve some of the problems connected with food and water supply in relation to movements and of the interrelations of the herbivorous animals with each other and their enemies.

A method of counting animals from a car is described and the factors that influence the results are discussed. Most important seem to be factors that influence the game in their movements and behaviour such as weather, food and water.

8,300 animals were seen during three visits in 820 miles' travelling. Tables are given showing the numbers of the six most frequently seen ungulates (impala, wildebeeste, zebra, kudu, waterbuck and giraffe) seen on two selected journeys: (a) between Skukuza and Punda Maria in August, and (b) between Pretorius Kop and Skukusa in May These examples serve to illustrate the method, and no conclusions are drawn at this stage of the enquiry.

South African Journal of Science, *Vol. XXXVI, pp. 386-389, December, 1939.*

ON THE "FRILLED" TADPOLE OF *BUFO CARENS* Smith

BY

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(Communicated by S. F. Bush).

Read 4 July, 1939.

The tadpoles of *Bufo carens* Smith are characterised by the possession of a delicate horseshoe-shaped fold or "frill" on the dorsal surface of the head and trunk. Power (1926: 115-117), who has described and figured the tadpoles, points out that they are capable of living in very stagnant water, in which they swim near the surface, and he suggests that the fold may "serve as a float . . . sustaining the head on the surface under adverse circumstances." However, the structure of the frill and its mode of use point clearly to its being respiratory in function; and, since a similar organ has, so far as we are aware, been described in no other tadpole, we have considered it worthy of further study.

Frill-Structure.

The frill extends as a thin, horseshoe-shaped fold from just behind the eyes to rather more than half-way back along the dorsal surface of the trunk, to which it is attached by its inner edge, the outer edge being free. The fold is deepest posteriorly, where it runs across the body, and tapers to nothing anteriorly just behind each eye. During swimming, the frill is raised slightly away from the body, and its free edge is in constant wave-like motion; but when the tadpole is at rest under the water, it lies flat and motionless.

Histologically, the frill is a simple fold of the skin, comprising both epidermal and dermal layers. It is richly supplied with blood-vessels, forming an extensive capillary network. The arterial supply consists of a pair of large vessels which are given off, one on each side, from the paired Cutaneous arteries near their origin from the Pulmo-cutaneous arches. The venous connections have not been fully worked out, but it appears that the blood from the frill runs by a pair of vessels into the Musculo-cutaneous veins.

Habits and Tadpole Behaviour.

The eggs of *Bufo carens** are deposited and undergo development in any stretch or pool of water, no matter how small; many of these pools become very warm during the daytime, and are thoroughly stagnant; in such water *B. regularis* does not normally occur.

Unlike the tadpoles of *B. regularis*, which are to be found scattered throughout their stretch of water, those of *B. carens* congregate, from the time of hatching, into large writhing masses, which at intervals rise rapidly to the surface of the water, and then slowly subside to resume feeding.

A comparison of the behaviour of these two species under various conditions serves to demonstrate the respiratory function of the frill, and the importance of this organ in highly stagnant water.

A large number of fairly advanced tadpoles of both species, captured in an old disused well, were transported to the laboratory in a very small container. Later they were transferred to an aquarium tank containing fresh, well-aerated tap-water. Large numbers of both species had died and the remainder took some time to recover from the effects of overcrowding. During this period the two species reacted differently. The *B. regularis* tadpoles remained at the surface swimming with their nostrils projecting above the water, and taking in gulps of air at short intervals. The *B. carens* tadpoles, on the other hand, rested at the surface with the body held horizontal, and the nostrils submersed, but with the frill slightly elevated above the surface, or actually lifting the surface-film with it. After recovery, all the tadpoles sank to the bottom of the tank and proceeded to feed.

The tadpoles completed their larval development in the aquarium, the water being kept well-aerated. As metamorphosis progressed, *B. regularis* spent a good deal of time at the surface taking in air direct from the atmosphere. Even when feeding, they made frequent trips to the surface for air. In *B. carens* the frill became larger and larger, reaching its greatest size when the tail began to be resorbed. These tadpoles, too, spent a good deal of time at the surface during this period, but always with the frill extended in the surface-film. When feeding, they did not make periodic trips to the surface for air as did *B. regularis*. As soon as the young frogs left the water, the frill was quickly reduced, and after some days had completely disappeared.

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* *Bufo carens* is widely distributed through Natal, Transvaal, Rhodesia and Portuguese East Africa (Rose, 1929: 71), and as far north as 1°S (Power, *loc. cit.*), being extremely abundant in the Transvaal and the midlands of Natal.

EXPERIMENTAL.

A large number of young tadpoles of *B. carens*, all in about the same stage of development, without limbs and with very small frill, was divided into three batches and placed in different containers. In one of these the water was kept fresh and well-aerated by constant changing; in another, the water was left unchanged; while to the third, decaying vegetable matter was added to pollute the water. The tadpoles, whatever the state of the water in which they were confined, throve and grew rapidly and more or less uniformly.

In the polluted water, the tadpoles developed large frills—not immediately, but when about half-grown. They would all float at the surface when full-fed, but when feeding, could remain for considerable periods at the bottom. *B. regularis* tadpoles, at the same stage of development, that were introduced into this tank, survived, but did not grow well and were soon outstripped by the frilled tadpoles. They were forced to spend so great a time at the surface of the water that their feeding was inadequate and growth retarded.

When they had reached the three-legged stage, tadpoles from the three batches were compared. It was obvious that the frill on the tadpoles confined to the fouled water was approximately twice as large as it was on those which had developed in the well-aerated water. The tadpoles in the unchanged water had frills of an intermediate size. Just before the end of metamorphosis the frills attained approximately the same size in all three batches.

A number of tadpoles from the tank containing the well-aerated water were introduced into the fouled water. These did not have their growth retarded in any way, but they showed a striking increase in the size of the frill within a period of three days. When the tadpoles were transferred from the fouled to the fresh water, their frills showed no appreciable decrease in size.

INDUCED BEHAVIOUR RESEMBLING THAT OF *B. regularis*.

Frilled tadpoles, at various stages of development, can be forced to travel to the surface of the water for gulps of air, in the fashion of *B. regularis*, by causing them to swim actively around for fairly long periods. But once they quieten down, they rely upon the frill to satisfy their respiratory needs.

A similar effect was produced by placing tadpoles with fairly-well developed frills in tap-water which had been boiled for a long time. Contrary to expectation, the frill did not increase in size but diminished, and the tadpoles gulped air at the surface in the manner of *B. regularis*.

It would appear that under extreme stress, the frill is incapable of furnishing a rapid enough respiratory-interchange,

and resort must be had to the method of swallowing air direct from the atmosphere.

SUMMARY.

1. The unique horseshoe-shaped "frill" on the dorsal surface of the head and trunk of the tadpoles of *Bufo carens* Smith is a simple skin-fold, furnished with an extensive reticulum of blood-capillaries, elaborated from the main Cutaneous vessels.

2. It appears to be a physiologically-controlled auxiliary respiratory mechanism, being specially well developed in very stagnant water, and during the later stages of metamorphosis. It attains its maximum size at the time when the tail begins to be resorbed, and disappears completely a short while after the young frogs have left the water.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVI, pp. 390-404, December, 1939.*

THE OLFACTORY ORGAN AND TENTACLES OF *XENOPUS LAEVIS*

BY

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With 9 Figures.

Read 4 July, 1939.

In descriptions of the adults of Xenopus (Gilchrist and von Bonde, 1919; Noble, 1923; Escher, 1925) it is usual to refer to a small protuberance beneath the eye as the "tentacle." As the length of this structure varies according to the species and is consequently used as one of the bases of specific differentiation (Noble, 1923), a few remarks regarding its significance do not seem to be irrelevant.

The larvae of Xenopus are characterised among other things by the possession of a pair of long slender tentacles situated on the upper lip at the corners of the mouth. These larval tentacles are solid structures supported by a slender rod of cartilage (c.tent., Figs. 5, 7, 8) which springs from the quadrato-ethmoidal cartilage (q.e.c., Fig. 5). The tentacles are inconspicuous in very young larvae, but are evident in nearly all other larval stages, being especially noticeable in larvae in which both fore- and hind-limbs are freed. They gradually decrease in length towards the end of the larval period, so that when metamorphosis is almost completed they are hardly noticeable as small stump-like projections, and in the young frog they have been completely absorbed.

Bles (1904) has homologised these larval tentacles with the balancers of Urodele larvae, and Peter (1930) refers to their comparison with a Siluroid form by some authorities. It certainly seems that they do subserve some sensory function, but it is difficult to determine whether that of touch or balance is the more accurate interpretation. From observations and experiments on larvae kept in aquaria injury to the tentacles has no apparent effect on the movements of the larvae. Immediately upon injury or amputation of one or both tentacles the movements are inclined to be rather clumsy, but the larvae soon seem to become accustomed to the loss of the tentacles and move about quite freely and apparently normally. They also remain

suspended at an angle in the water as do the uninjured larvae, and as far as can be observed their equilibrium is in no way affected. In older larvae the tail and limbs assist, of course, in maintaining the balance, but even younger larvae in which none of the limbs was evident seemed little affected by the removal of the tentacles, and development and metamorphosis progressed normally.

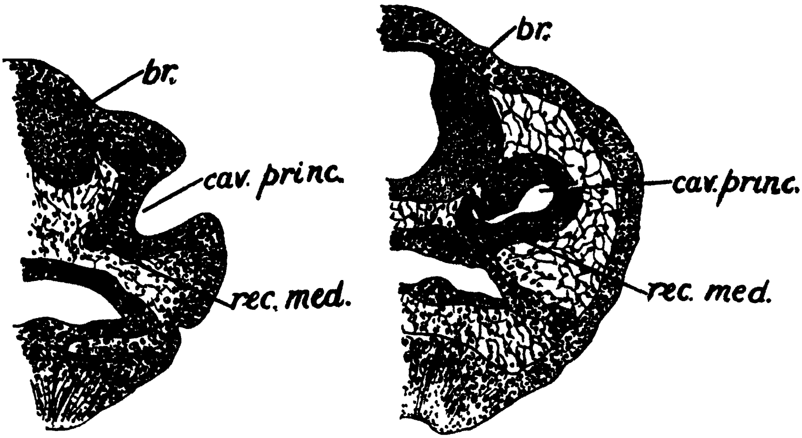

Fig. 1a. Fig. 1b.

Figs. 1a. and b.—Transverse sections of a larva measuring 5 75mm. long and in which the mouth is still closed. × 94. Fig. 1a. is 30μ anterior to Fig. 1b.

Neither does their morphology shed much light on the function of the larval tentacles. In section (Figs. 2, d and e), each tentacle is cylindrical, and its dermal part is roughly divided by connective tissue strands into two compartments. In the one nearer the body lies the supporting cartilage (c.tent.), and naturally the tentacular muscle also passes into this compartment to its insertion on the tentacular cartilage. This muscle (m.tent.) is comparatively short, for in a full-grown larva measuring 60 mm. long, the tentacular muscle extended only into the first sixteenth of the length of the tentacle. The outer compartment contains the tentacular nerve and blood vessels. The tentacle is at first innervated by a small terminal branch of the ramus mandibularis V (md.4, Figs. 2 d and e), whose composition is of motor and general cutaneous fibres. During metamorphosis when many of the cephalic structures, including the course of some of the nerves, are subjected to certain radical changes, the supply to the diminishing tentacles is derived from a terminal twig of the ramus ophthalmicus profundus V (op. Figs. 6 and 7), which in Xenopus consists of general cutaneous fibres. It is of interest in this connection to note that Engelhardt (1924) found that the tentacle of Ichthyophis, which he considered

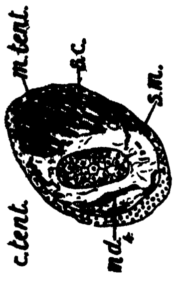

Fig. 2d.

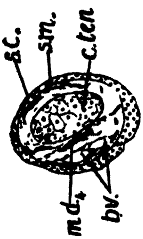

Fig. 2e.

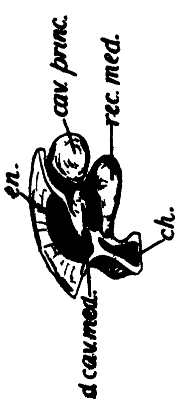

Fig. 2a.

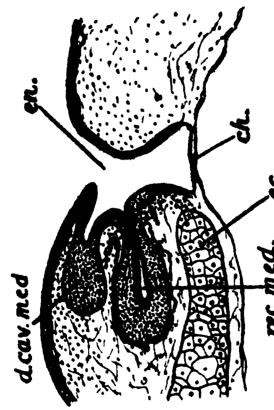

Fig. 2b.

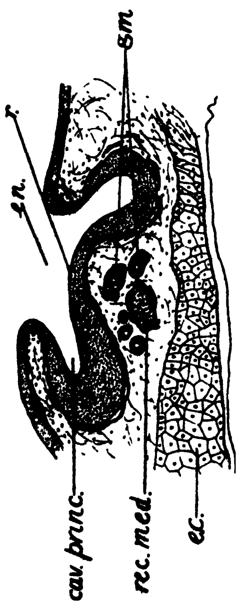

Fig.

Fig. 2a.—Sketch of wax model of the right olfactory organ of a larva measuring 60μ long: anterior view. $\times$ 25.

Figs. 2b. and c.—Transverse sections passing through the olfactory chambers of a larva measuring 60μ long. The sections are 150μ apart. $\times$ 50.

Figs. 2d. and e.—Transverse sections of the tentacle of the same larva as in Figs. 2a. – c. $\times$ 90. The section in Fig. 2e. is 400μ behind Fig 2d. In each of them the lateral surface of the body is a short distance above the section of the tentacle.

to be a purely tactile organ, was innervated by the ramus maxillaris V. In a previous article (1939), the writer has shown that this nerve is absent in Xenopus, the maxillary region being innervated by the ramus ophthalmicus profundus V. This peculiarity probably explains the unusual supply to the tentacle in the larval stage. The epidermis of the tentacle, as one would expect from the nerve supply, is not provided with any special sensory cells. It consists of the stratum corneum (s.c.) and stratum Malpighii (s.m., Figs 2, d and e), and is essentially similar to that covering the general body surface except for the absence of mucous glands.

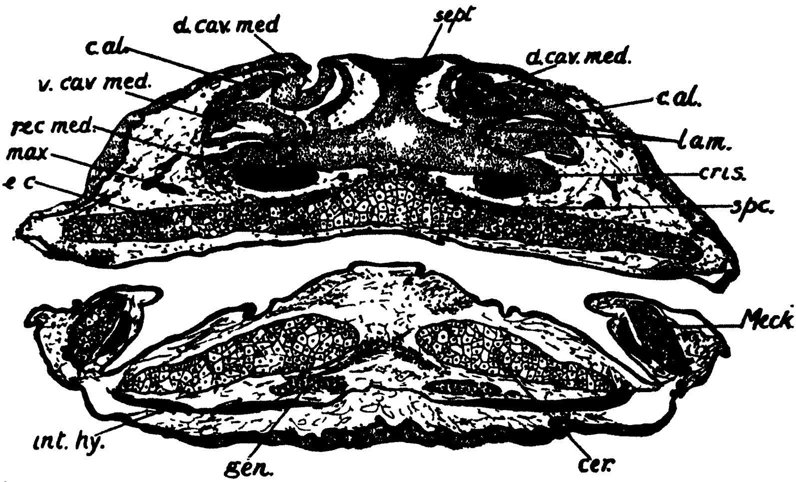

Fig. 3a —Transverse section through the head of a metamorphosing specimen showing the connection between the cartilago alaris and the crista intermedia. × 25.

From the above observations it must therefore be concluded that the larval tentacles, while they may assist in the maintenance of balance, they are not essential to it, and that although their morphology offers little solution to the problem of their function, the possibility that they may act as tactile organs cannot be overlooked.

These larval structures are in no way associated with the so-called adult " tentacles " which are located immediately ventral to the circumorbital lateral line sensory organs, and which only appear after the completion of metamorphosis. The fact that they have been termed " tentacles," however, indicates that their true significance has not previously been fully appreciated. It is true, of course, that this can only be revealed by microscopic studies of serial sections and such are not exactly relevant to the systematics of the genus.

During some recent observations on the morphology of the head of *Xenopus laevis* (Paterson, 1939), a study was made of

the nasal region in both larvae and young frogs. The larval olfactory organ is a simple construction lying above the ethmoidal cartilage of the chondrocranium (e.c., Figs. 2 b, c and 3 a, b). It arises very early in larval life as infoldings of the sensory ectoderm on each side of the anterior part of the brain. In young larvae measuring 5 mm. in total length, and in which the mouth is still closed, the organ consists of only a deep depression representing the future cavum principale (cav. princ., Figs. 1 a, b). From the medial wall of this, the recessus medialis of the cavum inferius or Jacobson's organ (rec.med., Figs. 1 a, b) develops early and rapidly assumes more definite proportions. As yet, the posterior communication with the buccal cavity has not been established.

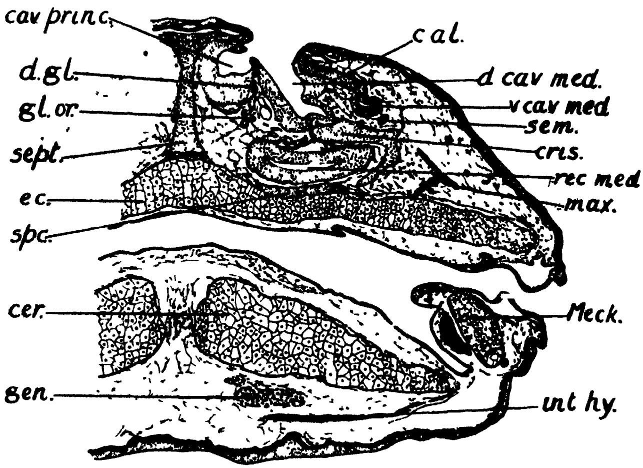

Fig. 3b.—Transverse section 120μ behind that shown in Fig 3a.

In subsequent larval stages the organ consists of an extensive cavum principale and a large recessus medialis. The latter (rec. med., Figs. 2 a, b, c) lies below the cavum principale and is anteriorly placed in the larva. Towards the close of larval life, and in stages in which the fore limbs have been freed, the cavum medium (d.cav.med., Figs. 2 a, b), arises anteriorly, the rudiment lying medially to the main passage. In metamorphosing specimens it is also anteriorly situated and opens to the outside (d.cav.med., Fig, 3a) in front of the external opening of the cavum principale (cav.princ., Fig. 3b), the latter being located about 120u behind the aperture of the cavum medium. Judging by the distance between Figs 2b and 2c, the two openings are, therefore, still approximately the same distance apart in the metamorphosing specimens as they are in the young larval stages. In all larval and metamorphosing stages the choane, which is more anterior in the larva than in the adult, is guarded by a horizontal fold of the epithelial lining of the mouth (mf., Fig 5).

During metamorphosis, the organ suddenly changes into a highly complex structure (Figs. 3 to 8), to which extensions and foldings of the sensory epithelium are added to the original cavities and the whole is supported above the ethmoidal cartilage (e.c., Figs. 3, a and b) by an intricate system of cartilages. The choane and the recessus medialis assume a more posterior position, and it becomes evident that the rudiment of the cavum medium seen in the larva develops into the dorsal compartment of this chamber in the adult. This dorsal compartment lies to the outside of and slightly ventral to the cavum principale, and the two open close to each other into the vestibule. The cavum medium becomes more complicated by the addition of a ventrolateral compartment (v.cav.med., Fig. 4), which in turn has a posterior thin-walled diverticulum.

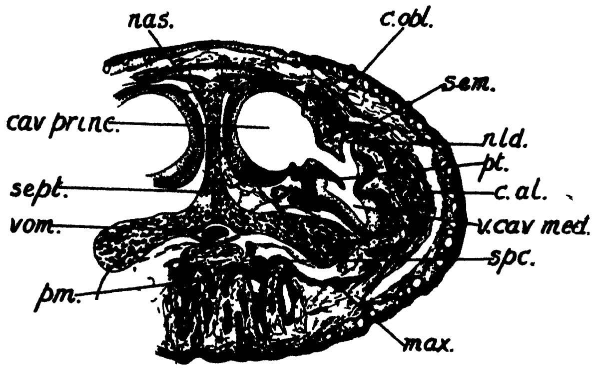

Fig. 4.—Transverse section through the head of a young frog showing the position of the ductus nasolacrimalis. × 25.

During metamorphosis the cavum principale (cav.princ., Figs. 3 to 7 and 9a) becomes extensive, but remains a relatively simple wide chamber. The horizontal membrane guarding the larval choane disappears, and the adult internal naris (ch., Figs. 7 and 9a) is a much wider aperture than that of the larva.

During larval life only the glandula nasalis medialis (gm., Fig. 2c) is present, and, as in the adult, it opens into the dorsal wall of the recessus medialis. The glandula oralis interna, a term applied by Foske (1934) to a medial gland (gl.or., Fig. 3b) opening into the floor of the cavum principale, appears during metamorphosis, as does also the glandula intermaxillaris (gim., Figs. 6 and 9a), which at first is situated well forward beneath the ethmoidal cartilage in the anterior part of the olfactory region. Towards the end of metamorphosis this gland, which is now more extensive, lies in the posterior half of the olfactory region below the praevomer (Figs. 6 and 9a). It is a paired gland which opens posteriorly into the mouth near the posterior limit of the choane.

The nasal cartilages develop rapidly from adjacent connective tissue and their arrangement soon resembles that of the young frog. The writer has previously (1939) indicated that these cartilages may broadly be compared with those of Rana, as described by Gaupp (1896 to 1904), the main differences being the larger size of the cartilago alaris and the absence of cartilago praenasalis inferior. It is also thought that a lamina superior, such as is found on the crista intermedia of Rana is absent in Xenopus, and in this connection a few observations additional to those previously recorded may be of interest. During the course of the present observations it was noticed that the cartilages at the anterior limit of the crista intermedia undergo some slight changes during the comparatively short period of formation of the nasal capsule, and the condition found in an early phase of metamorphosis requires special attention, as it may throw some

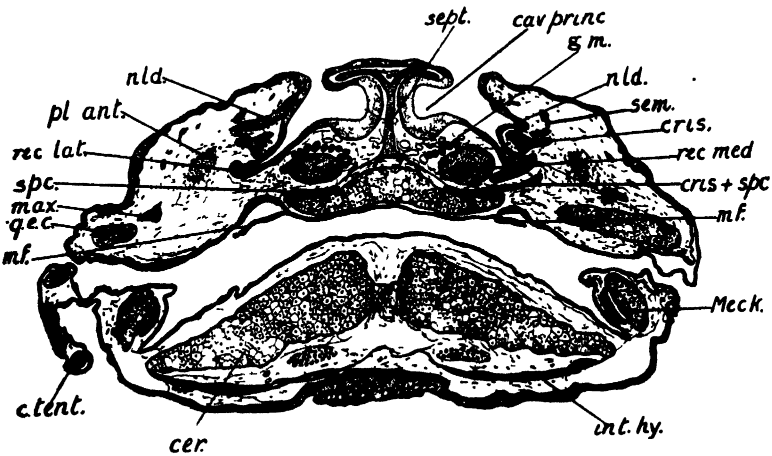

Fig. 5.—Transverse section through the head during metamorphosis showing two aspects of the ductus nasolacrimalis. × 21.

light on the apparent lack of a lamina superior in fully metamorphosed specimens. It has previously been noted by the present writer (1939) that the cartilago alaris (c.al., Figs 3 a and b and 4) is unusually large in Xenopus and constitutes the lateral wall of the capsule, forming a protection mainly for the large cavum medium. This cartilage is connected with the rest of the capsule at the anterior junction of the crista intermedia and the solum nasi, the connecting bridge passing between the dorsal and ventral compartments of the cavum medium. From a wax model made from serial sections of a specimen in an early phase of metamorphosis it appears as though the crista intermedia supports a somewhat Y-shaped cartilage which extends between the dorsal and ventral compartments of the cavum medium and practically surrounds the dorsal compartment. As may be seen in Fig. 3a, the short stem of the Y arises from the

crista intermedia, while the outer limb of the Y. which passes between the dorsal and ventral compartments of the cavum medium, fuses with and supports the cartilago alaris (c.al., Fig. 3 a and b). The inner or medial limb forms the inner supporting wall for the dorsal compartment of the cavum medium and also fuses with the cartilago alaris anteriorly. Had the cavum principale been more anterior in position during the early period of metamorphosis, this bridge and its vertical medial limb (lam., Fig. 3a) would have formed a partition between the cavum principale and the cavum medium, as does the lamina superior in typical adult Anura. As may be observed from Fig. 3a, however, the cavum principale is not yet evident in the section, and rather more posteriorly (Fig. 3b), when the cavum principale is established, the bridge between the crista intermedia and the cartilago alaris has disappeared from the sections.

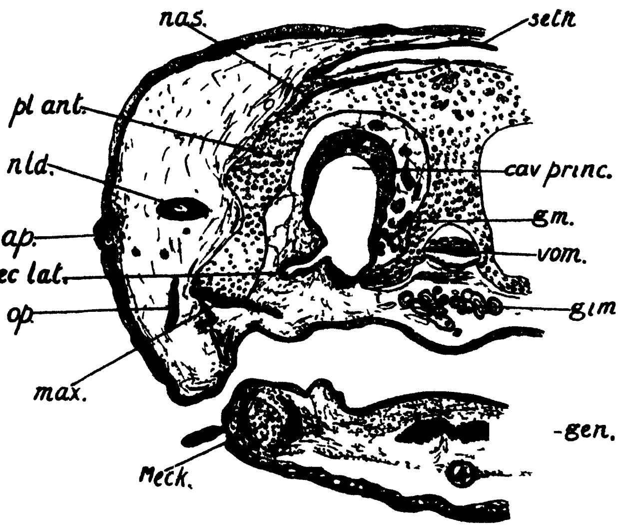

Fig 6 —Transverse section of a metamorphosing specimen passing through the small transient aperture of the ductus nasolacrimalis. × 25.

In fully metamorphosed specimens the medial limb of the Y-shaped cartilage becomes reduced, but the outer limb still retains its connection with the cartilago alaris and also passes between the dorsal and ventral compartments of the cavum medium. It may therefore be deduced that owing to its large size, the cartilago alaris requires a broader attachment to the medial structures of the capsule and perhaps for this reason a typical lamina superior is not developed from the crista intermedia. During metamorphosis, however, the arrangement of the cartilages are temporarily suggestive of the presence of a lamina superior, but owing to the disposition of the olfactory chambers at this stage, the lamina does not assume its typical position,

and by the time the chambers have taken up their permanent position part of the cartilage has disappeared.

After metamorphosis the dorsal compartment of the cavum medium opens to the exterior rather more indirectly, and in addition another connection with the exterior is established. Arising from the dorsolateral wall of the isthmus between the two compartments of the cavum medium is a long slender backwardly-directed duct, which shortly after metamorphosis begins opens on to the lateral wall of the head anterior to the eye by two apertures (Figs. 6 to 8). One of these openings (ap., Fig. 6) is inconspicuous and subsequently disappears. The main aperture (nld., Fig. 7) opens about 60-70μ behind this transient one

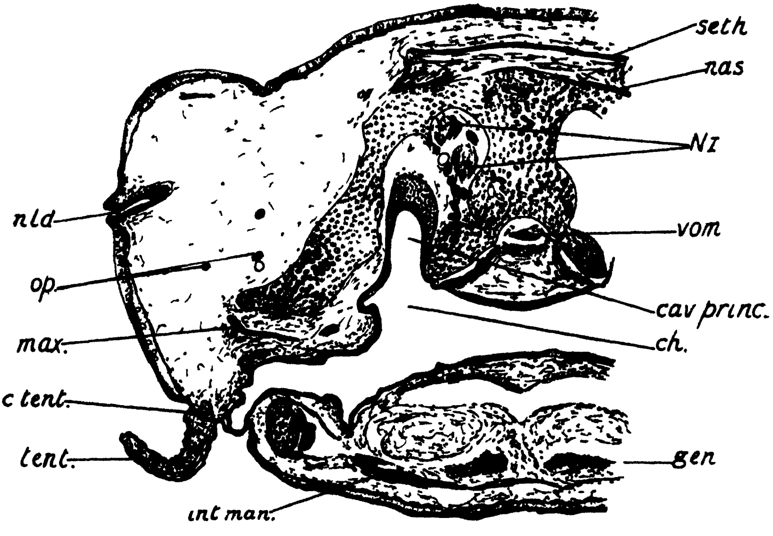

Fig. 7.—Transverse section through the head of a metamorphosing specimen showing the permanent aperture of the ductus nasolacrimalis. The vestige of the larval tentacle is still evident. × 24.

and is evident even in forms in which there is a fairly large vestige of the larval tentacle (tent., Fig. 7). During metamorphosis the main aperture causes a slight protuberance of the epidermis (Fig. 7) but in the young frog, in which the tube describes a similar course but is continued farther posteriorly so that it opens on the side of the head beneath the eye, the epidermis surrounding the original aperture is prolonged into a small finger-like projection. This appendage (nld., Fig. 9a) constitutes the so-called adult "tentacle," and the duct from the cavum medium passes down it and discharges at its extremity. It is considered that it is directly comparable with the ductus nasolacrimalis of other Anura, where, however, it is not continued into a tentacle-like outgrowth.

As early as 1905 and 1906 Cohn indicated that the tentacle of the adult Xenopus had a canal-like lumen which extended into the nasal cavity. He compared its development with the tentacle-apparatus of *Ichthyophis glutinosa*, regarding which Gadow (1920) has also remarked that "the whole structure is possibly an offshoot of the nasolacrymal duct." Engelhardt, however, from his study of the morphology and innervation of the tentacle-apparatus of Ichthyophis (1924) has concluded that

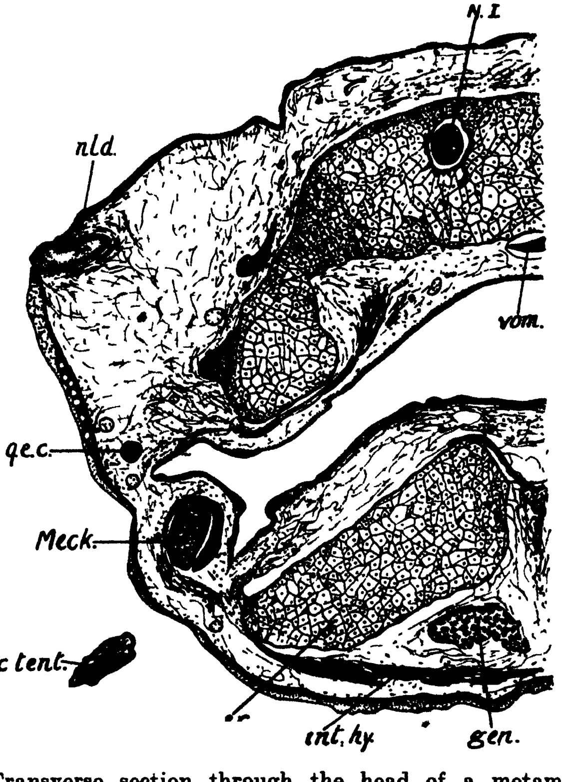

Fig. 8.—Transverse section through the head of a metamorphosing specimen showing the bifurcation of the ductus nasolacrimalis and also the permanent aperture. × 25.

it is a purely tactile organ, a view which seems to be borne out by Matthes' account (1934) of the olfactory organ in Amphibia, including the Gymnophiona. Matthes shows that as in the Urodela there is a short duct in the Gymnophiona connected with the Jacobson's organ. This duct opens by two short branches into the margin of the tentacle pit, but Matthes does not accept the interpretation of Laubman (1927) and Marcus (1930) that the duct and the Jacobson's organ constitute in themselves a special olfactory organ in the Gymnophiona. Recently de Villiers (1938) and de Jager (1938) have made obser-

vations on the cranial anatomy of other species of Gymnophiona and concur with Engelhardt's findings on the distribution of the cranial nerves. It is therefore apparent that there is no similarity between the tentacles of the Gymnophiona and the so-called "tentacles" of adult Xenopus, for in the former the tentacle itself is not connected with the nasolacrimal duct and in Xenopus no sensory function can be attributed to the "tentacle."

Cohn's interpretation of the parts of the larval olfactory organ are somewhat inaccurate, and his conclusions regarding the development of the adult "tentacle" are therefore open to criticism. He has concluded that the rudiment of the "tentacle-apparatus" appears in the larva as a canal in which three regions are recognisable. Behind the naris the canal has an obvious lumen and ends blindly, but in front of the naris it forms a

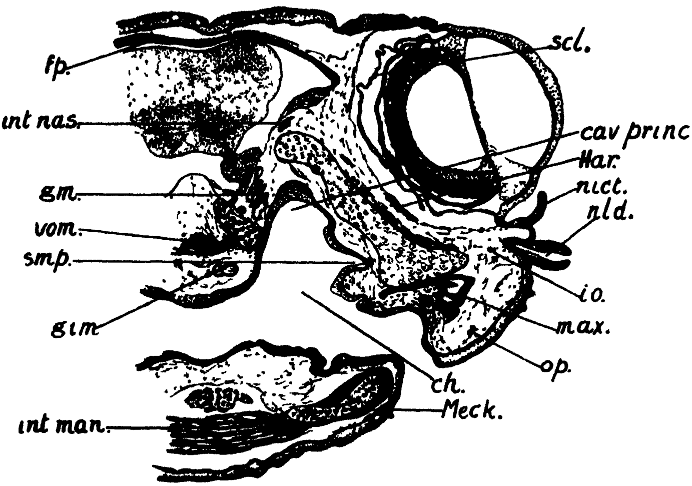

Fig. 9a.—Transverse section of young frog showing the aperture of the ductus nasolacrimalis beneath the eye. × 25.

blindly-ending solid cord of epithelium. In the region of the external naris the rudiment forms a ridge composed of epithelium similar to that comprising the canal itself. The canal, which he depicts in his Fig. 7 (1906), seems to be the posterior part of the larval cavum principale. In the present series of sections the posterior limit of the external naris lies about 80μ behind the level of the section shown in Fig 2c, and posteriorly to this the cavum principale in section is similar to the blindly-ending canal described by Cohn. In front of the external naris the recessus medialis of the cavum inferius (Jacobson's organ) is obvious in sections (rec.med., Figs. 2 b and c). It is solid anteriorly and posteriorly (Fig. 2c), but as it approaches the main nasal passage (Fig. 2b), its lumen becomes more apparent. The front portion of the recessus medialis seems to represent the anterior solid

rudiment observed by Cohn. The epithelial ridge (r., Fig. 2c) connecting these two parts is in line with the opening of the recessus medialis into the main passage between the larval external and internal nares, and continues posteriorly into the posterior part of the cavum principale.

Although he did not seem to associate the canal in Xenopus with the ductus nasolacrimalis of other Amphibia, Cohn considered that the " tentacle-apparatus " developed as a solid cord of epithelium which later sank below the epidermis and acquired a lumen. These conclusions are probably due to his having interpreted the solid and canaliculised structures of the larval olfactory organ as definite portions of the rudiment of the adult

Fig. b.

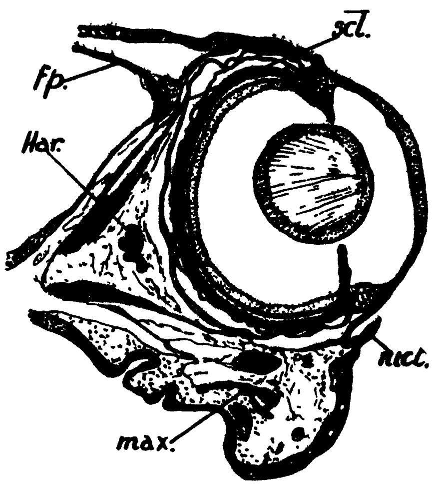

Fig. 9c.

Fig. 9b.—Transverse section 100μ anterior to Fig 9a., passing through the aperture of the Harderian gland. × 27.

Fig. 9c.—Transverse section 250μ posterior to Fig. 9a. The orbit has been sectioned and the position of the Harderian gland is indicated. × 27.

" tentacle-apparatus." As has just been shown, however, these two parts of the larval organ are distinct nasal chambers that can be identified with the arrangement obtaining in the adult. There seems to be no indication that the duct of the adult is foreshadowed in the larva. The ductus nasolacrimalis of the adult (nld., Fig. 4) is connected with the dorsolateral wall of the cavum medium opposite the plica terminalis (pt., Fig. 4) and only becomes apparent during metamorphosis. The structures described by Cohn are medial and not lateral to the main passage as is the ductus nasolacrimalis of the adult. Therefore, although Cohn has recorded the presence of a canaliculised " tentacle " in Xenopus, his conclusions regarding its origin and development from larval structures cannot be substantiated.

More recently (1934) the olfactory organ of Xenopus has been the subject of a very thorough investigation by Föske. He refers to the duct as the " Tränennasengang " and finds that in his Stadium 10, which compares with a larva in a slightly earlier phase of metamorphosis than the one sectioned in Fig. 3 of the present series, it appears as a *solid* epithelial structure connected with the isthmus between the dorsal and ventral divisions of the " Nebenhöhle." Föske inclines to the view that the ductus nasolacrimalis of Xenopus develops from the lower layer of the epidermis and after sinking beneath the epidermis establishes connection with the middle blind sac. He was, however, unable to find a developmental stage in support of this view, but has suggested that such a stage must be of very short duration.

The present writer has also failed to find any indication that, as in other Amphibia, the ductus nasolacrimalis of Xenopus may develop as a separate solid epithelial cord. As is seen on the left hand of the section in Fig 5, the ductus nasolacrimalis (nld.) may resemble an almost solid cord of epithelium in which there is hardly any trace of a lumen. When, however, it is traced to the wall of the cavum medium it is seen, as on the right half of the section (Fig. 5), to be a direct evagination of the wall of this chamber. The lumen is at first only evident in the immediate vicinity of the cavum medium, but as the ductus extends more posteriorly the central passage rapidly becomes established throughout its whole length and eventually opens at the ostium nasolacrimale on the side of the head. There is therefore no definite evidence that in Xenopus the ductus nasolacrimalis arises as two separate parts which later unite, and it is thought that the condition observed in the present series of metamorphosing specimens suggests that it develops during metamorphosis simply as an extension of the wall of the cavum medium.

The morphology of the nasal organ gives no indication of the function of the ductus nasolacrimalis, and Föske doubts that it acts as an outlet for the secretion of the nasal glands. The large glandula nasalis medialis (gm., Figs. 5, 6) discharges into the recessus medialis and the duct from the glandula oralis interna (d.gl., Fig. 3b) opens into a marked glandular portion of the floor of the cavum principale at approximately the same level at which the ductus nasolacrimalis communicates with the cavum medium. The remaining gland, the glandula intermaxillare, which Föske regards as the " Rachendrüse " opens posteriorly into the roof of the mouth. There is a possibility that some of the secretion of the glandula oralis interna may pass out through the ductus nasolacrimalis, but there is little likelihood of that from the glandula nasalis medialis passing forward into the cavum medium and so to the duct.

It is therefore to be noted that the duct in Xenopus, due to the fact that it has no communication with the orbit, does not function like the nasolacrimal duct of higher Vertebrates.

As has been shown, it opens to the exterior below the eye (nld., Fig 9a), and immediately above its tentacle-like projection is the nictitating membrane (nict., Figs. 9 a, b and c), which also develops during metamorphosis. The reason for the duct opening thus can be explained by the fact that in Xenopus there are no movable eyelids. Had a lower eyelid been present, the duct would have been directed inward towards the eye and its aperture would then have been comparable with the punctum lacrimale of higher forms. It is also to be noted that in Xenopus there is no lacrimal gland. The only gland in the orbit is the Harderian gland, a small portion of which (Har.) may be seen in Figs. 9 a and c. It appears during metamorphosis in the anterior part of the orbit and opens antero-ventrally (Har.ap., Fig. 9b) at the inner margin of the nictitating membrane between the latter and the conjuctiva bulbi.

SUMMARY.

Attention is drawn to the fact that the tentacles, so characteristic of the larvae of Xenopus, are absorbed during metamorphosis and are therefore in no way associated with the so-called " tentacles " of the adult. The larval tentacles are considered to be either tactile or balancing organs, whereas the adult structure is merely the opening of the ductus nasolacrimalis, which, due to the fact that there are no movable eyelids, does not open into the corner of the orbit, but projects laterally beneath the nictitating membrane. The ductus nasolacrimalis may be traced to the isthmus between the dorsal and ventral compartments of the cavum medium. Some notes are given regarding the larval and adult olfactory organ and the nasal cartilages that develop during metamorphosis.

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LETTERING USED IN FIGURES.

a.p., small transient aperture of ductus nasolacrimalis; *br.*, brain; *bv.*, tentacular blood-vessels; *c. al.*, cartilago alaris; *cav. princ.*, cavum principale; *cer.*, ceratohyale; *ch.*, choane; *c. obl.*, cartilago obliqua; *cris.*, crista intermedia; *c. tent.*, tentacular cartilage; *d. cav. med.*, dorsal compartment of cavum medium; *d. gl.*, duct of glandula oralis interna; *e.c.*, ethmoidal cartilage; *en.*, external naris; *fp.*, fronto-parietale; *gen.*, musculus geniohyoideus; *gim.*, glandula intermaxillaris; *gl. or.*, glandula oralis interna; *gm.*, glandula nasalis medialis; *Har.*, Harderian gland; *Har. ap.*, aperture of Harderian gland; *int. hy.*, musculus interhyoideus; *int. man.*, musculus intermandibularis; *io.*, truncus infraorbitalis; *lam.*, lamina superior during metamorphosis; *max.*, maxillare; *Meck.*, Meckel's cartilage; md_4, tentacular nerve; *mf.*, fold over choane in larva; *m. tent.*, tentacular muscle; *nas.*, nasale; *nict.*, nictitating membrane; *nld.*, ductus nasolacrimale; *NI.*, nervus olfactorius. *op.*, branches of ramus ophthalmicus profundus V; *pl. ant.*, planum antorbitale; *pm.*, premaxillare; *pt.*, plica terminale; *q.e.c.*, quadrato-ethmoidal cartilage; *r.*, epithelial ridge in larval olfactory organ; *rec.lat.*, recessus lateralis; *rec.med.*, recessus medialis; *s.c.*, stratum corneum; *scl.*, sclerotic cartilage; *sem.*, septomaxillare; *sept.*, septum nasi; *seth.*, supra-ethmoid; *sm.*, stratum Malpighii; *smp.*, sulcus maxillopalatinus; *spc.*, superior prenasal cartilage; *v. cav. med.*, ventral compartment of carvum medium; *vom.*, praevomer.

South African Journal of Science, *Vol. XXXVI, p. 405, December, 1939.*

WAARNEMINGS OP DIE LEWENSLOOP VAN *BUNOSTOMUM TRIGONOCEPHALUM* (RUDOLPHI 1808), 'N HAAKWURM VAN SKAPE EN BOKKE

DEUR

R. J. Ortlepp,

Afdeling Parasitologie, Onderstepoort.

Gelees op 4 Julie 1939

Opsomming.

1. Onder gunstige omstandighede van lug, temperatuur en vogtigheid kan eiers, verkry van die mis van skape of bokke of van die uteri van dragtige ooie, binne 24 tot 36 uur uitbroei.

2. Daar is drie voorparasitiese larwestadia, elk waarvan met 'n vervelling beeindig word. Die vel van die tweede stadium word nie afgegooi nie, maar word deur die derde of besmettlike stadium larve behou as 'n beskermende skede. Die derde stadium word binne vyf tot agt dae bereik vanaf die larwe uitgebroei het.

3. Die derde stadium larwe is morfologies en biologies feitelik indenties met die van die haakwurm *Gaigeria pachyscelis.*

4. Die besmetting van die gasheer vind plaas of deur die vel, wat die larwes deurboor, of deur die bek.

5. Na die larwes die vel deurboor het gaan hulle na die longe, heelwaarskynlik deur middel van die bloedstroom; hulle bereik die orgaan binne ses dae. In die longe bly hulle vir omtrent vyf dae en in die periode groei hulle en bereik die vierde stadium wat met 'n voorlopige mondkapsel voorsien is.

6. Die larwes trek nou na die dunderm langs die weg gorrel, bek en slukderm. Die eerste larwes wat in die dunderm gevind word het alreeds die skede van die derde stadium afgegooi, maar daar het nog geen geslagsonderskeiding plaasgevind nie; die onderskeiding word slegs omtrent vier dae later bereik. By die tyd het tande aan die basis van die mondkapsel al ontwikkel.

7. Die larwes byt vas aan die vlokke van die dunderm en leef van die bloed van die gasheer. Hulle groei en in omtrent 'n week gaan hulle oor na die vyfde of laaste stadium.

8. Die laaste vervelling vind omtrent 10 dae later plaas.

9. Die larwes vreet en groei en die volwasse of eierleggende stadium word in nege of 10 weke bereik vanaf die datum van besmetting.

South African Journal of Science, *Vol. XXXVI, pp. 406-407, December, 1939.*

PUBERTY AND ADOLESCENCE IN A BABOON (*PAPIO PORCARIUS*)

BY

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Read 4 July, 1939.

Abstract.

The perineal skin of the adult female baboon undergoes cyclical fluctuation in size during the menstrual cycle. Before puberty, however, the perineum is quiescent. The first evidence that the baboon is approaching puberty is to be found in the sexual skin which commences to increase rhythmically in size.

Baboon 24 joined the colony in the Anatomy Department in February, 1935; we have now been able to estimate her age at that time as being approximately 2 years. The nature of the perineal rhythm in this animal from the onset of puberty to the end of adolescence is summarised in Table I.

The regular menstrual cycle using only bleeding as a landmark becomes established in this animal after the first cycle and is fairly constant throughout the whole progress of adolescence. It is not possible to assess the maturity of the baboon by considering alone the length of the menstrual cycle on the basis of the intervals between the bleedings.

The perineal measurements reveal that there is a rhythm of growth in the perineum and that the perineum increases progressively in size with each cycle. This lends support to Hartmann's " staircase phenomenon of growth."

From a study of the growth of the perineum it appears that puberty was initiated when this animal was a little over 4 years of age and that this animal reached maturity when it was between 5½ to 6 years old.

Acknowledgments.

I wish to express my thanks to Professor Dart for his advice and for providing facilities in his department; to the Royal Society of London and the Research Grant Board for the financial grants which assisted this investigation.

TABLE I.

A summary of the Menstrual Cycles during Puberty and Adolescence.

No. of cycle	Menstruation in days	Turgescence in days	Deturgescence in days	Perineal rest in days	Total length of cycle in days	Maximum size of Perineum in inches
1	—	28	*	*	47	7
2	3	21	*	*	38	6½
3	3	19	10	9	38	7½
4	3	16	9	10	35	8½
5	4	16	8	13	37	9½
6	4	19	11	7	37	10
7	3	17	?	?	39	11
8	5	16	11	13	40	10
9	4	21	13	6	40	10
10	4	17	11	9	37	14
11	4	18	12	11	41	14
12	3	? 22	? 9	10	41	15½
13	4	20	—	—	40	?
14	4	20	9	10	39	16½
15	5	18	10	10	38	16½

* On account of the double peak it has not been possible to determine the end point.

South African Journal of Science, *Vol. XXXVI, pp. 408-411, December, 1939.*

ON THE AFFINITIES OF THE SOUTH AFRICAN PLEISTOCENE ANTHROPOIDS

BY

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Read 6 July, 1939.

In 1925 Prof. Dart startled the world with the announcement of the discovery of the skull of a new type of antropoid ape, which he called *Australopithecus africanus*. The skull, which was discovered in a limetone cave near Taungs, is that of a young anthropoid child with the milk teeth still functional. It has a brain of about 500 cc. Dart held that its systematic position is somewhere between the living anthropoids and man, and that it is probably closely allied to the anthropoid that was the human ancestor.

Dart's first paper was published in " Nature " (7.2.1925). He gave a good preliminary account of the skull, but his illustrations were too small to be quite satisfactory, and his conclusions were too startling to be readily accepted by all. He held that *Australopithecus* was a member of an " ultra-simian and pre-human stock " and that it was near the ancestor of man.

I ran up to Johannesburg within a few weeks of the announcement of the discovery of the Taungs skull, and stayed a couple of days with Prof. Dart, and made a most careful examination of the skull. I agreed that in the main Dart had come to the right conclusion.

I sent off a short paper to " Nature " and one to the " American Museum Journal," stating that though *Australopithecus* is an anthropoid ape somewhat resembling the chimpanzee in size and general appearance, it is not closely allied and is undoubtedly near the line that led to man and thus near to the human ancestor.

In 1929 I published a good figure of the side view of the milk teeth of *Australopithecus* and showed that they are very unlike those of the chimpanzee and gorilla but closely resemble those of man.

Shortly after this Dart carefully removed the lower jaw from the upper, and we were able for the first time to see satisfactorily the occlusal surfaces of the milk teeth. These fully confirmed what had been seen in side view, and showed

that in practically all details of structure these milk teeth resemble those of man, and differ entirely from those of the living apes.

In 1930 I stated "There can thus be little doubt that *Australopithecus*, though an anthropoid near in general structure to the chimpanzee, is on or near the line that resulted in man, and thus closely allied to the ancestral antropoid."

In 1936 I resolved to hunt for the skull of an adult *Australopithecus* in the caves of the Transvaal and within a few weeks was successful. In 1938 I was further successful in getting a second skull. Each of these types is allied to *Australopithecus*, and all three belong to the same family, but for reasons which cannot be entered into in this short communication I consider that all three belong to distinct genera. The 1936 type was found at Sterkfontein and may be referred to as the Sterkfontein skull. The 1938 discovery was found at Kromdraai and may be called the Kromdraai skull. The Sterkfontein skull I place in the genus *Plesianthropus*, and the Kromdraai in the genus *Paranthropus*.

The mammalian fuana associated with the Sterkfontein ape is now satisfactorily known: that associated with the Kromdraai ape fairly well known; and that associated with the Taungs ape slightly known. We can thus state with considerable confidence that the Sterkfontein ape is a Middle Pleistocene form; and the Kromdraai ape also Middle Pleistocene, but probably many thousands of years earlier that the Sterkfontein, while the Taungs ape is probably Lower Pleistocene.

When the Taungs ape lived the conditions were practically desert. The rainfall was probably under six inches. When the Sterkfontein and the Kromdraai apes lived the rainfall was a little more than to-day, probably about 25 to 30 inches; but clearly the conditions did not differ much from those of, say, the Northern Transvaal of to-day.

The dentitions of the Kromdraai and of the Sterkfontein apes are satisfactorily known; while the Taungs ape gives the almost perfect milk dentition. These three dentitions show us that we have in the Australopithecinae a family of anthropoids which still have small brains of 450 to 650 cc., but have evolved teeth on quite human lines.

The Australopithecines are anthropoids with brains a little larger than the living gorilla and chimpanzee, and with small supra-orbital ridges and with glenoid regions of the human type but with practically human teeth.

Were nothing known of these anthropoids but their teeth, probably most zoologists would place them somewhere in the human family. That they are closely allied is, I think, beyond question. Being Pleistocene forms, they cannot be ancestral to man, but they are probably the survivors of Pliocene apes which

may have been widely spread over Africa and perhaps Southern Asia. And it is probably from some member or members of this family that man arose. Not improbably *Eoanthropus*, *Pithecanthropus* and *Homo* may have originated from different genera of Australopithecines.

It is interesting to note that the teeth of our Transvaal Australopithecines approach more nearly to those of *Homo* than they do to those of *Pithecanthropus*, *Sinanthropus* and *Eoanthropus*; and it seems not unlikely that *Homo* arose independently of *Pithecanthropus*, *Sinanthropus* and *Eoanthropus* in Pliocene times.

The origin of the Australopithecines is a little more difficult to settle as our knowledge of the Pliocene fossil anthropoids is rather meagre. Lewis has recently revealed a couple of most interesting genera from the Siwaliks, *Sugrivapithecus* and *Bramapithecus;* while Pilgrim, Brown and others have given us other allied types, especially *Sivapithecus*. These are, however, only known by teeth and imperfect jaws. The teeth are in a number of characters a little more human than are those of the chimpanzee and gorilla.

Sugrivapithecus and *Bramapithecus* are evidently anthropoids allied to the chimpanzee but a little nearer to man; while *Sivapithecus* is also allied to the chimpanzee, and a little further from the human line than *Sugrivapithecus* and *Bramapithecus*.

The gorilla has teeth that differ from the human mainly in being much larger and in having the cusps more pointed, but in my opinion the gorilla teeth are nearer to those of man than are those of the chimpanzee.

It has been held that man with the comparatively low rounded cusps on his molar and premolars could not have come from an anthropoid like the gorilla with its pointed cusps; but this objection is of little weight. The sea otter with its rounded low cusps has certainly been evolved from a form like the common otter with pointed cusps, and nature could have as easily evolved a molar like that of man from one with pointed cusps such as we find in the gorilla.

A more serious difficulty is met with in the milk molars. The milk molars of *Australopithecus* and of man could not, in my opinion have been derived from the types found in the gorilla and chimpanzee. And I think we must conclude that *Australopithecus* and man have retained a modification of the milk molars found in the *Cercopithecids* which has been lost in the living anthropoids. We do not know what types were present in *Dryopithecus* and the Siwalik apes. When we know this we shall be able to decide whether the human line branched off from the chimpanzee and the gorilla lines in *Miocene* or *Pliocene*.. But whether the branching took place in *Miocene* or Pliocene, the Australopithecinae were almost certainly in the human line in the Pliocene.

Gigantopithecus of von Koenigswald, known only by a couple of teeth is evidently an anthropoid larger than the gorilla. The second upper molar agrees so closely with that of *Paranthropus* that I incline to think *Gigantopithecus* will prove to be a member of the Australopithecinae.

A few years ago I argued that man must have evolved from a heavily built ape, otherwise he would have lost his great toe, just as the kangaroo has lost its first toe. If man was evolved from a giant ape like *Gigantopithecus* we may have here the clue to man's large brain. Large mammals usually have large brains, and when they have descendants that are smaller in body the brains usually remain relatively large. Possibly *Gigantopithecus* will prove to have had a brain of 700 to 900 cc., and man may be one of his descendants who developed a more feeble body but retained the large brain.

The discovery of the Australopithecine apes seems to completely disprove the views of Osborn and Wood Jones, and to render it almost certain that the human line was evolved some time during the Pliocene and not improbably as recently as Upper Pliocene—possibly 2,000,000 years ago.

South African Journal of Science, *Vol. XXXVI, pp. 412-416, December, 1939.*

ON A COLLECTION OF FOSSIL MAMMALIAN REMAINS FROM THE VAAL RIVER GRAVELS AT PNIEL

BY

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With 2 Text Figures.

Read 6 July, 1939.

The Power Collection of stone implements, collected by Mr. J. H. Power of Kimberley and presented to the Bureau of Archæology, includes a small collection of twenty-nine fossilised mammalian teeth from the Vaal River gravels at Pniel. The fossils were collected from the dumps thrown up by miners working for diamonds, and these workings are confined to the horizons designated " Younger Gravels " in the recent Vaal River survey (Söhnge, etc., 1937). The implements associated with the fossils belong exclusively to phases of the Stellenbosch culture; more advanced artefacts are lacking. Since, furthermore, the fossilisation of all the specimens is practically complete, and most of them are partly encrusted with ferruginous material in a manner typical of specimens from these horizons, it is considered that they all belong to the Younger Gravels.

To the best of the writer's knowledge, no faunal assemblage from particular horizons of the Vaal gravels has as yet been described; it is therefore of considerable interest to record the twelve species represented in this small collection. The majority of these have already been mentioned by other authors, but there occur also a new species of horse and remains of several antelopes not readily identified with the modern species. It is hoped that detailed investigations of modern ungulate dentition will enable the writer to name these forms with greater certainty at some future time.

Order Perissodactyla—Family Equidae.

Equus (Stercohippus) poweri sp.nov.

The type of this new species (Fig. 1) is a well-worn right upper first molar, the roots and part of the base of which are broken and damaged. As preserved, the height is 45 mm., the breadth 28 mm., and the length 24 mm., so that it is somewhat broader than long. The enamel pattern is simple and probably somewhat degenerate, the most distinctive feature being the fusion of the hypocone and hypostyle with the result that, in the lower part of the tooth at least, the normally characteristic

posterior fold is absent. There is a very faint indication that a small fold might have been present in earlier stages of wear. Another important feature is the partial fusion of the protocone and protoconule with a consequent reduction in the anterior fold. The protocone is small and somewhat rounded. There is no caballine fold. The fossettes are simple, the prefossette possessing only a small pli-prefossette and possible pli-protoconule, the postfossette being simple and rather rectangular than lunate. The inner wall of the prefossette lies diagonally, whereas the inner wall of the postfossette is parallel to an antero-posterior line. The outer wall is thick and the parastyle has an external groove. The tooth is closest in affinities to *E.*(*S.*) *harrisi* (Broom) (1928) but differs from it in many respects. It is possible that the new species is a degenerate offshoot of the same stock. The specific name is given in honour of the collector, Mr. J. H. Power.

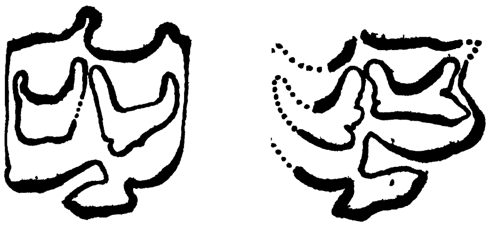

Fig. 1.—*Equus* (*Stereohippus*) *poweri* Cooke. Type right upper first molar and doubtful left upper third molar.

An upper left third molar, also shown in Fig. 1, probably belongs to the same species, though the folding of the fossettes is more complicated, and their shape is closer to that found in the molar on which van Hoepen (1930) created the genus *Stereohippus*. The posterior fold is lacking, though this is not of such great importance in a third molar. The form of the protocone, however, is almost identical with the new type and quite distinct from *E.*(*S.*) *harrisi*. The height of the tooth as preserved, the roots being absent, is 59 mm., the breadth is 26 mm., and the approximate length 30 mm.

Equus capensis Broom.

Three lower teeth of this well-known species are present in the collection, and their enamel patterns are shown in Fig. 2.

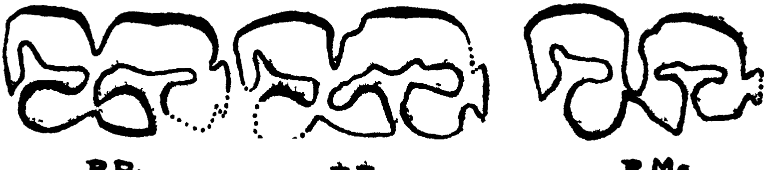

Fig. 2.—*Equus capensis* Broom. Right lower cheek teeth.

Two are right fourth pre-molars, one of which is almost identical with that figured by Haughton (1932) as a neotype. The other is a right second molar with the posterior root preserved.

Equus cf. *cawoodi* Broom.

A damaged upper right molar, possibly the fourth pre-molar is referred to this species. The caballine fold is clearly present and the folding of the fossettes is closely comparable to that shown in the type figured by Broom (1928). The breadth of the tooth, however, is only 24 mm. as compared with 31 mm. in the type. The anterior half of the prefossette and protocone are absent, so that the length cannot be measured. The angle of wear was very oblique. There are some affinities with *E. kuhni*.

Another much damaged upper right molar occurs of which only the postfossette, a small portion of the prefossette and the posterior portion of the ectoloph, including the mesostyle, is preserved. The molar was quite unworn, but on cutting 20 mm. below the unworn crown shows a pattern again with affinities towards *E. cawoodi* and *E. kuhni*.

Equus (*Hippotigris*) *burchellii* (Gray).

A right lower second molar, a left lower second molar and two left upper third molars may be assigned to this species. The lower molars are typical, but the two upper molars are somewhat doubtful owing to the wide variations commonly found in third molars of the quagga group. The sub-generic name *Hippotigris* is used to qualify *Equus* for the reasons already put forward by van Hoepen (1932).

ORDER ARTIODACTYLA—SUBORDER RUMINANTIA—FAMILY BOVIDAE.

Alcelaphus sp.

One lower left second molar is referable to this genus. It differs considerably from *A. caama* but is close to *A. cokii*.

Connochaetes sp.

A broken lower left second molar is doubtfully referred to *Connochaetes*.

Kobus aff. *ellipsiprymnus*.

A lower left first molar is very similar indeed to the corresponding molar of the living waterbuck.

cf. *Taurotragus* sp.

Five molars of a large antelope resembling *Taurotragus* are present, but it is doubtful if they actually fall within that genus. All the teeth are practically unworn and sectioning is not helpful as the angle of wear plays an important part in affecting the apparent pattern. More detailed study of the antelopes is necessary before proper description is possible.

SUBORDER SUINA—FAMILY HIPPOPOTAMIDAE.

Hippopotamus amphibius (Linn.)

A lower right third molar and a broken upper right second molar are very similar indeed to the living species. There are some differences, but they are not of a magnitude such as to justify specific distinction. The posterior portion of an unworn third molar and two fragments of canines also occur.

Hippopotamus sp.

A broken upper incisor in an extreme state of fossilisation differs markedly from the living species, and is not referable to the inadequately figured extinct forms. It is probably a smaller and extinct species such as that mentioned by Dreyer and Lyle (1931) though not specifically distinguished by them.

FAMILY SUIDAE.

Phacochoerus aethiopicus (Pall.)

Two typical third molars, one an upper left and the other a lower right, are referred to this species. The upper molar is higher than is usual, measuring 61 mm. near the posterior end.

ORDER PROBOSCIDEA—FAMILY ELEPHANTIDAE.

Archidiskodon sp.

Three posterior plates of a lower (?) left molar and a worn fragment of a median plate represent some species of *Archidiskodon*. The fragment is quite indeterminable, and the three plates do not fit readily into the described species. The height is 148 mm., the " length " 84 mm. at the base and the plates taper upwards sharply so that at the grinding surface it is only 34 mm. The plates curve posteriorly towards the roots and the side of each plate is nodular. The greatest width of any plate is 78 mm. and the grinding surface 47 mm. There is very little wear, the posterior plate comprising four partly-worn islets and one unworn conelet. The enamel is 2 to 3 mm. thick and little crimped. In general it appears to belong to the *planifrons* group, but is both higher and narrower than the known species and specific identification cannot yet be made.

Grouping the specimens according to degree of fossilisation, it is found that the *Hippopotamus* incisor and the *Archidiskodon* molars are extremely impregnated, the equine and *Phacochoerus* molars less so, and the antelope teeth and *Hippopotamus amphibius* remains still less so, though nevertheless thoroughly fossilised. This would imply a general relative order of age which, indeed, is most probable. *Hippopotamus amphibius*, *Phacochoerus aethiopicus* and *Hippotigris burchellii* are living but palæontologically old species. The antelopes may be living, but are quite probably extinct forms, and the remaining five species are certainly extinct. Even if, as seems probable, the two most heavily impregnated specimens are oldest and derived from

older deposits, the Younger Gravels assemblage indicates that deposition occupied a considerable period of time. Although the Pleistocene in South Africa is not yet accurately defined or correlated with other known areas, a generally Middle Pleistocene age may nevertheless be suggested for the Younger Gravels as a whole.

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PHYSIOLOGICAL ASPECTS OF RUMINANT DIGESTION

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INTRODUCTION.

Although in the past numerous scientific investigations have been conducted on problems relating to the nutrition of animals, it is a significant fact that comparatively little is as yet known about the intricacies of the digestive process in such economically important species as cattle and sheep. These animals, belonging to the group usually referred to as ruminants, are endowed with a digestive tract far more specialised than that found in most of the other species of mammals. Thus, in order to enable them to digest the coarse fibrous plant materials usually constituting the major part of their diet, a preliminary disintegration of the food mass is conducted within a series of forestomachs. During this stage, there is, however, no possibility of the ordinary digestive secretions of the animal playing any important role, since the saliva in these species is devoid of diastatic enzymes, while in the rumen and other forestomachs the epithelial lining is well cornified, thus again precluding any active secretion. Consequently, whatever disintegration does take place within these compartments is due to mechanical action, especially during the remastication or rumination of the food mass which, by that time, has already undergone partial softening and maceration in the forestomachs. In this it is aided by the ample moisture conditions as well as by the rhythmic churning and kneading movements to which the ingesta is continually exposed while in the rumen.

Besides the above-mentioned mechanical processes, various significant chemical changes, largely of a fermentative character, are occasioned principally by the rich and varied microscopic flora and fauna which inhabit this part of the digestive tract and in which such essential requirements as moisture, heat, control of hydrogen ion concentration and the removal of metabolites are all fully met. In this way the food undergoes a carefully controlled acid fermentation which, in many respects, is similar to that occurring within a silo rather than to the putrefactive breakdown of food residues caused by the bacterial flora of the large intestine. It is only after this process of fermentation that

the ingesta becomes exposed to the action of the digestive juices in the true stomach (abomasum) and the intestines. Various phases of the physiology of the ruminant forestomachs have been studied by Mangold and his co-workers, also by Czepa and Stigler, Trautmann, Wester, Scheunert, Krzywanek, Dukes and Sampson, Schalk and Amadon, and much information has already been gained, especially with regard to the motility of the forestomachs and the act of rumination. With regard to the actual processes of fermentation and the factors controlling these, as well as the relative significance of this phase as compared with that of true digestion, our knowledge is as yet very incomplete.

It was for this reason that an extensive programme of research was undertaken at Onderstepoort. In this work adult merino sheep were selected as experimental animals, although a few cattle have also been utilised mainly for comparative purposes.

Experimental Technique.

In order to study the function of any part of the digestive tract, it is essential that it be readily accessible for whatever work is to be carried out. For this purpose a system was adopted in which permanent fistulae were created at various levels of the tract by the insertion of ebonite tubes into the lumen of the bowel. The free ends of the tubes were withdrawn through stab wounds through the abdominal wall, the tubes being kept closed by rubber stoppers. On such fistula animals kept on a fixed diet, a wide variety of experiments could be conducted over long periods, the animals remaining in perfect health.

The following brief description of the experiments, and also of some of the results already obtained, will serve to indicate the wide possibilities which this technique offers.

(a) *Kymographic Recording of Ruminal Motility.*

As mentioned before, the rhythmic movements of an organ such as the rumen is of great physiological significance for it is by these means that the food mass is adequately mixed, the consistence controlled, and the gas which generates during fermentation allowed to escape through the oesophagus.

By means of suitable rubber tubing, the fistula is connected through a water manometer with a recording membrane tambour. In this way all pressure changes occurring within the rumen are accurately recorded on a slow moving clockwork drum while the maximal and minimal pressures can be read off on the manometer. During the actual recording the animal is kept standing quietly in a specially constructed crush pen. An analysis of the graphs thus obtained reveals the following points:—

(1) Before feeding, the rumen undergoes approximately 5 to 7 sharp rhthmic contractions per 5 minute period, each movement fluctuating between zero and up to 100 m.m.

water pressure at the height of contraction. At times the minimal pressure actually falls below zero as a result of the sucking action of the fully relaxed rumen.

(2) The moment that feeding is started, the rhythm of the rumen is accelerated frequently up to 22 movements per 5 minute period, although there is no significant rise in intraruminal pressure. This acceleration appears to be associated with vagal reflexes during deglutition, since the normal rhythm soon returns after cessation of feeding.

(3) Various chemical agents administered to the animal cause marked changes in ruminal activity. Thus, solutions of copper sulphate, nicotine sulphate and silver nitrate when dosed on to the back of the tongue provoke striking acceleration of movements similar to those noticed during feeding, while solutions of ferrous sulphate, magnesium sulphate, sodium chloride, and alum, dosed in the same manner, cause no alteration in the rhythm. Minute amounts of potassium cyanide, on the other hand, cause a severe paralysis of the rumen from which it may only recover after 30 to 120 minutes depending on the dose.

(b) *Manometric Recording of Gas Generated from Rumen.*

These experiments were devised primarily with the object of studying the rate of fermentation in the rumen and also of the factors leading to hoven or bloating which, in ruminants, frequently terminates fatally. For this purpose continuous recording of the gas volumes in the rumen is conducted by means of a large graduated water manometer suitably connected to the fistula tube. Readings of the gas volumes at constant (atmospheric pressures are taken every 5 minutes. Apart from recording of the volumes, this method also allows for the easy collection of gas samples for analysis.

Data obtained thus far, show (1) that in the morning, before feeding, practically no gas is generated within the rumen.

(2) There is a rapid rise in the amount of gas during and immediately after feeding, especially on a diet of lucerne hay. On various types of grass hay, gas records are usually lower than for lucerne, while for starchy foods such as maize meal, there is no immediate increase in the gas. These results indicate the wide differences in the rate at which the various foods are fermented in the rumen.

(3) Animals kept on an adequate diet of lucerne hay and maize are capable of fermenting test doses of glucose (of which 50 gram amounts are usually dosed directly into the rumen) far more rapidly than when they have been kept on a poor veld hay diet for some weeks.

(4) Concentrations of 1:9,000 copper sulphate added to ruminal ingesta readily inhibit the fermentation of test doses of glucose, whereas concentrations of 1:4,500 of potassium cyanide

fail to influence the fermentation to any significant degree. Sodium fluoride in a concentration above 1:900 fails to inhibit fermentation.

(c) *Chemical Analysis of Ruminal Ingesta.*

In order to study the chemical changes which the food undergoes within the forestomachs, test samples of ingesta can be readily withdrawn from the rumen by aspiration through a glass tube which is inserted through the fistula into the depth of the mass. By repeating this collection both before and at various intervals after the feeding of a test meal, the rate and nature of the chemical change undergone by the food can be accurately followed.

Studies along these lines, conducted in collaboration with Mr. S. Myburgh, have shown that ruminal ingesta is strongly buffered round about pH7 in spite of the constant formation of considerable amounts of organic acids derived mainly from the fermentation of carbohydrates. This buffering is maintained largely by the copious flow of alkaline saliva as well as by the proteins ingested. Instead of feeding the various test substances per os, these may also be conveniently dosed directly through a funnel inserted into the fistula tube, thus obviating delayed ingestion which is frequently noticed in animals.

(d) *Suspension of Substances Within the Rumen.*

In order to ascertain the rate at which different materials are disintegrated within the rumen purely as the result of bacterial and other chemical changes (i.e. prevented from being regurgitated to the mouth for mechanical breakdown as in rumination), small quantities of such food substances as maize and other types of grain, also selected parts of plants such as grass stems and leaves, are enclosed within separate compartments of small cylindrical bags. These bags, which are about 6 cms. long, are made from a loosely woven, very fine and thin natural silk. After being filled, they are inserted through the fistula and tied at one end to a short length of surgical silk by means of which they are kept suspended in the ruminal mass, the free end of the silk thread being fastened to the stopper. In this way the material is exposed to the action of the bacteria and other organisms as well as to any free enzymes which may be present in solution. These bags are periodically withdrawn from the rumen, and after being washed in running tap water, they are opened and the contents examined, if necessary also microscopically. Results obtained thus far indicate (1) that whole material suspended in the rumen is disintegrated relatively much slower than similar material fed through the mouth and which is thereby exposed to mechanical breakdown in addition to the chemical action, (2) that starches and sugars contained within the grain and other plant tissues undergo disintegration far more rapidly than the supporting structure which is comprised mainly of cellulose and lignin. After the disappearance of the "soft" parts, the skeletal pattern of the material becomes readily visible.

(e) *Study of the Microscopic Flora and Fauna of the Rumen.*

As mentioned above, the rumen of a healthy animal supports a very large and varied flora of bacteria and other closely allied forms, as well as large numbers of infusoria and other protozoa. Taken as a whole, these organisms exert a profoundly important influence on the process of food fermentation within the fore-stomachs, although little is as yet known about the relative significance of the different types or of the factors controlling their growth and multiplication. It is obvious that a lack of this basic knowledge precludes any clear conception as to the digestion, and thus also to the wider aspects of nutrition in ruminant animals. Moreover, it becomes impossible to follow the pathogenesis of the manifold digestive and metabolic disturbances to which these species are subject. It is for this reason that an extensive programme of research work has been initiated in collaboration with Mr. J. G. v.d. Wath and Miss R. McAnally.

Detailed bacterial and infusorial counts which have been carried out thus far on ruminal ingesta, reveal the fact that their numbers rise and fall with the adequacy or otherwise of the daily diet of the animal apart from relative fluctuations in the different species of organisms. Of the different methods adopted for the isolation and study of the most significant species of bacteria in the rumen, it appears that these are readily attracted to some specific food substances suspended in silk bags as described above, and hence allows for the ready cultivation in vitro of these organisms from scrapings taken from the surface of the "bait" set out for them. In addition to this, experiments are at present in progress with the object of elucidating the nature of the enzymes elaborated by these organisms and of the factors influencing their activity.

(f) *Recording of Intraruminal Temperatures.*

In order to ascertain whether the process of fermentation in the forestomachs is associated with any rise of temperature within that organ, a system has been devised whereby standardised clinical thermometers with their upper ends firmly secured in short lengths of rubber tubing are suspended in the ingesta through the fistula tube. Except for the moment when the thermometer is inserted, the fistula is kept securely closed throughout. At the same time, rectal temperatures are also recorded and plotted against the ruminal temperatures which are taken regularly every 30 minutes during the course of an experiment. From a large volume of data thus collected from ten sheep, the following findings may be noted:

(1) In the early morning, before feeding has taken place, all ruminal temperatures usually fall within the range of 101·5°F. to 102°F., being approximately 0·5°F. above that of the rectum.

(2) There is a very slight but definite rise in the ruminal temperature of fasting animals during the course of the day.

This, however, seldom amounts to more than 0·5°F., and reaches its maximum in the late afternoon.

(3) The feeding of lucerne hay (500 grams) leads to a prompt rise of 4°F. to 6°F., i.e., to values of 105-107°F. The onset of this elevation is visible soon after feeding has commenced, and reaches its maximum in less than one hour after consumption of the feed. Following this, there is a gradual lowering of the temperature during the next few hours. Likewise, the feeding of teff and grass hay also provokes a similar type of temperature elevation, although to a less striking degree.

(4) The feeding of a wide variety of concentrated starchy foods such as maize meal provokes little, if any, response in the temperature. On the other hand, such sugars as glucose and sucrose produce a definite, though much lower rise than that found with the different types of hay.

(5) Any rise in the rumen temperature is followed by a corresponding elevation in rectal temperature which, however, regularly shows a lag period of 1 to 2 hours behind that of the rumen.

(6) These elevations in ruminal temperature are intimately associated with the rapidity and extent of the fermentation, and hence they serve as an index of the chemical changes occurring within the rumen.

Summary.

There are striking peculiarities in the digestion of ruminant animals which are, however, as yet poorly understood. Through the presence of a series of large and irregularly formed diverticula or forestomachs, the food mass is exposed to the fermenting action of a dense culture of bacteria and other organisms. During this phase, even coarse plant materials are disintegrated with the formation of different organic acids and large volumes of gas. It is only after this process has been completed, together with that of rumination, that the ingesta is passed through to the true digestive organs, where further breakdown is caused by the digestive enzymes of the body.

In order to study this predigestion in the forestomachs, closed permanent fistulae are created in the rumen. On these fistula animals a wide variety of experiments can be carried out. Thus, in a study of the motility of this organ, it can be shown that its normal rhythm is strikingly influenced by a wide variety of factors. Moreover, it is found that large volumes of gas are formed during active fermentation which again is subject to numerous factors.

By direct and repeated collection of ingesta through the fistulae, the chemical changes undergone by the food can be closely followed, as well as the nature and the density of the micro-organisms and their enzymes studied. By suspending test

materials within the rumen, a study can be made of the speed and character of their disintegration as the result of the bacteriological activity. Accompanying this fermentation, there is a well marked rise of temperature within the rumen which serves as an index of the activity of the process.

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THYROIED EN BYNIER-CORTEX GEDURENDE LIGGAAMSOEFENING

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Liggaamsoefening oor 'n lang tydperk vervoorsaak 'n hypertrophie van die bynier (Donaldson en Meeser, 1932-33) wat hoofsaaklik beperk is tot die cortex (v. Beznák en Sarkady, 1933). Dat hierdie kortikale bynier-hypertrophie te wyte is aan 'n Vitamin B-tekort in the dieet is aangetoon deur v. Beznák en Persjés (1935). Hierdie ondersoekers maak die stelling dat die Vitamin B-gehalte van die dieet, die algemene stofwisselingshoogte en die volume van die bynier-cortex in baie nou verband met mekaar staan. Word rotte, wat op 'n voldoende Vitamin B bevattende dieet normaal voortlewe, aan oefening onderwerp, waardeur die algemene stofwisseling styg, dan reageer die byniercortex daarop deur 'n hypertrophie. Word aan die dieet gedurende die oefening meer Vitamin B toegevoeg as wat in die rustoestand nodig is, dan tree die hypertrophie met oefening nie op nie.

Ook Cowgill, Deuel, Smith, Klotz en Beard (1932) meen dat die behoefte aan Vitamin B met die arbeid saamhang slegs in soverre dit die stofwisseling verhoog. Cowgill en Palmieri (1933) het bv. aan duiwe op 'n Vitamin B voldoende dieet daagliks 100 mg. thyroïed gegee, waarna hulle simptome van Vitamin B-tekort begin toon het. Ook die waarnemings van Momose (1933) in hierdie verband is besonder interessant. Hy het nl. gevind dat as by rotte thyroïed aan die dieet toegevoeg word daar 'n hypertrophie van die bynier ontstaan. Aan die hand van v. Beznák en Persjés se stelling (loc. cit.) sou hierdie verskynsel verklaar kon word deur aan te neem dat die thyroïed-voeding die stofwisseling verhoog het waardeur die Vitamin B voorraad in die dieet ontoereikend geword het en sodoende gelei het tot 'n hypertrophie van die bynier-cortex. Momose meen egter dat hy ook in die bynier-medulla 'n volume-toename kon waarneem.

Eagle, Britton en Kline (1932) het verdere bewys vir hierdie verband tussen stofwisseling en bynier-cortex gelewer. Hulle vind dat as 'n ekstrak van die bynier-cortex vir 'n hond ingespuit word, dit sy arbeidsvermoë met 100 per sent. verhoog, soos gemeet in die oefenwiel.

Die doel van die huidige ondersoek was om hierdie veband tussen stofwisseling en bynier-cortex-volume noukeuriger na

te gaan veral om vas te stel in hoeverre die thyroïed aan hierdie verband 'n deel het, aangesien laasgenoemde die endokrine orgaan is wat in die laaste instansie die stofwisseling beheer. 'n Poging is ook gemaak om vas te stel in hoeverre die byniermedulla hypertrophieer gedurende die hyperthyroïde toestand.

Metode.

Sowat 50 rotte is vir die proewe gebruik; hulle was almal ongeveer vier maande oud. Aangesien die bynier-cortex by wyfies gedurende oestrus hypertrophieer (Anderson en Kennedy, 1932) is gelyke aantalle mannetjies en wyfies in elke proef gebruik. Deurdat swangerskap weer 'n atrophie teweegbring (Donaldson, 1924), is die twee geslagte in aparte hokke gehou. Al die proefdiere is geteel uit Wistar Institute-stamdiere en is gehou op 'n konstante dieet genoegsaam gebalanseerd om hulle in goeie gesondheid te hou. Die Vitamin B-gehalte van die dieet, in die vorm van bakkersgis, was net genoeg om gedurende die rustoestand normaliteit in all opsigte te verseker.

Die 50 rotte is vir die ondersoek in vyf groepe van tien elk verdeel. Hierdie groepe is as volg behandel:

Groep 1—Thyroidektomie sonder Oefening.

By hierdie diere is die thyroïed in sy geheel met sukses operatief verwyder. Gedurende die verdere verloop van die eksperiment is hulle op die gewone dieet gehou. Slegs in één geval was daar 'n aanduiding by autopsie, aan die end van die eksperiment, dat 'n klein gedeelte van die thyroïed-isthmus agtergebly het. Typiese myxoedemateuse simptome het duidelik die hypothyroidale toestand aangetoon maar origens was die diere heeltemaal normaal

Groep 2—Thyroidektomie met Oefening.

By nege van hierdie diere is die thyroied operatief met sukses verwyder. Gedurende oefening, soos later uiteengesit, het hulle uitgesproke traagheid vertoon en is hulle die meeste van die tyd in die oefenwiel teësinnig rondgeslinger. Dit is natuurlik wat verwag sou word as gevolg van die hypothyroidisme. Oefening, in die sin dat hulle self aktief daaraan deelgeneem het, kan dit dus nie bestempel word nie. Die toestande egter was, wat die oefening betref, vir hierdie proefdiere presies dieselfde as vir die normale kontroles en hulle kan dus met laasgenoemdes vergelyk word.

Groep 3—Thyroïed-voeding.

Aan hierdie diere is daagliks vir die eerste week twee tablette synthetiese thyroxien (Schering-Kahlbaum) gegee, volgens die fabrikante gelykstaande met ·75 gram gedroogde thyroïed-substansie. Die tablette is gewoonweg fyngemaal en met die kos gemeng. Vir die tweede week is elkeen elke dag ingespuit met ·001 gram thyroxien (B.D.H.) in 1 cc. normale soutoplossing. Hierdie groep is aan geen oefening onderwerp nie.

Groep 4—Kontrole sonder Oefening.

Hierdie diere het op die gewone basale dieet bly voortlewe en het geen oefening ontvang nie.

Groep 5—Kontrole met oefening.

Hierdie diere is onderwerp aan die veertiendaagse oefening soos hieronder beskrywe.

Oefening.

Groepe 2 en 5 is geoefen in 'n ,, Oefenwiel " teen 'n spoed van een omwinding in gemiddeld 10 sekonde d.w.s. teen 'n snelheid van 2,250 vt. per uur. Deur middel van voorafgaande toetse is vasgestel dat die rotte hierdie snelheid die beste verdra. In 'n vinniger bewegende wiel word hulle eenvoudig rondgeslinger. Gedurende die eerste twee dae van die eksperiment, voordat die diere hulle aan die ongewone omstandighede aangepas het, het hulle allerlei onnodige pogings aangewend om van die draaiende loopvlak weg te kom. Al gou egter het hulle ontdek dat die minste inspanning nodig is as hulle voortbeweeg in die teenoorgestelde rigting van die draaiende loopvlak.

Al die rotte van die genoemde twee groepe is vir veertien dae elke dag onderwerp aan drie uur oefening in hierdie oefenwiel. Om algehele uitputting te voorkom is hulle vir half uur periodes geoefen met 'n half uur rus tussen elk: een en 'n half uur in die oggend en net so lank in die middag. Die totale afstand wat deur elke rot per dag afgelê is kom dus te staan op een en 'n kwart myl. Soos reeds gemeld het die geopereerde diere nie self veel aan die oefening meegemaak nie en selfs nog aan die end van die veertiendaagse tydperk is hulle nog maar in die wiel rondgeslinger. Wanneer hulle wel geloop het was dit gewoontlik met baie teenstribbeling.

Na die eksperiment is al die diere van al die groepe met chloroform gedood. Die byniere is versigtig verwyder, sorgvuldig ontbloot van alle vet, fascia en vogtigheid en elke paar geweeg in 'n weegfles. Ook is die liggaamsgewigte van die rotte voor en na die eksperiment geneem en die gemiddelde waarde bereken. Om die relatiewe volumes van cortex en medulla vas te stel is vier byniere uit elke groep, onmiddelik nadat hulle geweeg is, gefikseer in Zender se vloeistof. Daarna is hulle ingebed gesny en gekleur met Haematoxylin en Eosien. Vir die volume-bepalings is elke tiende snit op geruite millimeter-papier geprojekteer teen 'n vergroting van 50x, en die omtrekke afgeteken. Hieruit is dan, met inagneming van die snitdikte, die volume van die cortex en medulla bereken.

Resultate.

Tabel 1 gee die liggaams- en bynier-gewigte van die diere in die verskillende groepe aan. Tabel 2 gee die relatiewe volumes van medulla en cortex in die groepe se byniere weer.

TABEL 1.

Nommer	1	2	3	4	5	6	7	8	9	10	Gem.
	M	W	M	W	M	W	M	W	M	W	
Groep 1											
Gem. Ligs. gewig (gram) ...	357	256	371	283	—	213	332	—	294	267	296·6
Bynier-gewig (milligram) ...	38·7	33·2	30·1	28·7	—	29·5	31·3	—	37 3	32·1	32·6
Groep 2.											
Gem. Ligs. gewig (gram) ...	261	196	301	291	341	—	231	203	287	212	258
Bynier-gewig (milligram) ...	39·4	37·1	40·2	34·7	29·5	—	33·0	37·8	35·3	38·6	36·2
Groep 3.											
Gem. Ligs. gewig (gram) ...	290	186	206	171	284	198	317	261	254	185	235
Bynier-gewig (milligram) ..	41·9	53·4	62·1	39·7	49·8	46·3	51·6	60·4	41·5	47·3	49·4
Groep 4.											
Gem. Ligs. gewig (gram) ...	332	194	297	212	316	231	294	197	265	201	254
Bynier-gewig (milligram) ...	42·1	31·9	35·2	44·6	30·7	37·2	38·5	40·4	39·6	39·9	38
Groep 5											
Gem. Ligs. gewig (gram) ...	284	168	228	212	233	197	281	211	302	250	215
Bynier-gewig (milligram) ...	68·3	45·7	61·1	54·4	46·6	55·8	78·6	52·3	66·3	43·1	57·2

TABEL 2.

Relatiewe Volumes van Medulla en Kortex van bynier. kub.mm.

	Groep 1	*Groep 2*	*Groep 3*	*Groep 4*	*Groep 5*
Totale klier ...	16·13	15·07	16·91	15·34	18·76
Medulla	2·0	1·8	1·67	1·71	1·61
Cortex	14·13	13·27	15·21	13·16	17·15
Cortex/Medulla	7·06	7·37	9·1	7·75	10·65

Uit Tabel 1 blyk baie duidelik dat oefening sonder verhoging van die Vitamin B-inhoud van die dieet 'n geweldige hypertrophie van die bynier veroorsaak, nl. tot 19·2 mg. Uit Tabel 2 kan vasgestel word dat hierdie hypertrophie hoofsaaklik die cortex geld. Thyroïed-voeding het ongeveer dieselfde uitwerking as oefening, nl. 'n hypertrophie, wat, volgens Tabel 2 uitsluitelik beperk is tot die cortex. Die bewering van Momose dat hy met thyroïed-voeding ook 'n hypertrophie van die medulla kry kon dus nie deur hierdie proewe bewaarheid word nie. Wat betref thyroidektomie skyn dit asof die verwydering van die thyroïed 'n geringe mate van inkrimping veroorsaak, nie soseer wat die absolute volume as gewig van die bynier betref nie. Gedwonge oefening, alhoewel dit moontlik die basale metabolisme effens mag verhoog, skyn tog in die afwesigheid van die thyroïed geen merkbare invloed op die bynier uit te oefen nie.

BESPREKING.

Die resultate verkry in hierdie eksperimente bewys baie duidelik dat daar 'n baie nou verband bestaan tussen die thyroïed en die bynier-cortex. Die hypertrophie van die bynier-cortex na thyroïed-behandeling tesame met die feit dat na vewydering van laasgenoemde klier daar met oefening geen soortgelyke hypertrophie optree nie, is myns insiens, 'n duidelike bewys dat die verband hier nie soseer gaan oor stofwisseling en bynier-cortex nie as wel oor thyroïed en bynier-cortex. Dit is dus die sekreet van die thyroïed wat in die afwesigheid van genoegsaam Vitamin B die bynier-cortex tot hypertrophie prikkel.

Dat daar so 'n direkte verband tussen thyroïed en bynier-cortex bestaan is in die bestaande literatuur herhaaldelik, alhoewel vaag, aangedui. So bv. beweer verskeie ondersoekers. o.a. Oehme (1936), dat daar 'n soort van antagonisme bestaan tussen thyroxien en cortien. Ook vir die hyperthyroïede toestande, soos

Graves se siekte is, volgens 'n aantal werkers, o.a. Hartman (1932), behandeling met bynier-cortex-ekstrak met goeie gevolge aangewend.

Na verwydering van die bynier-cortex tree die bekende simptome van spierverswakking en vermindering van reflektoriese prikkelbaarheid op. Word sulke diere ingespuit met bynier-cortex-ekstrak dan verdwyn die simptome onmiddelik (Pfiffner en Swingle, 1930). Csik en v. Ludány (1933) het self duidelik kon aantoon dat die bynier-cortex-hormoon nodig is vir die herstelfase van spier-arbeid. Britton en Silvette (1932) gaan selfs verder en voer bewyse aan dat die bynier-cortex-hormoon van net soveel belang is vir die spier-kontraksie as insulien.

Vir spier-arbeid kan dus die onderlinge werking van die volgende gepostuleer word, nl. die bynier-cortex-hormoon, thyroxien, insulien en Vitamin B van die dieet.

Opsomming.

1. Behandeling van rotte met thyroxien het dieselfde uitwerking as oefening, nl. 'n hypertrophie van die bynier, solank die Vitamin B-voorraad van die dieet slegs voldoende bly vir die rustoestand.

2. Die bynier-hypertrophie, hetsy opgewek deur oefening of deur behandeling met thyroxien is, hoofsaaklik beperk tot die cortex.

3. Thyroidektomie veroorsaak by die rustende dier 'n klein mate van involusie van die bynier-cortex.

4. Oefening na thyroidektomie veroorsaak nie 'n hypertrophie van die bynier-cortex nie.

5. Die gevolgtrekking word gemaak dat die hypertrophie van die bynier-cortex met oefening in die eerste instansie te wyte is aan 'n hyperaktiwiteit van die thyroïed, en tussen thyroxien en cortien sou daar 'n antagonisme bestaan.

6 Uit die eksperimente en literatuur word 'n verband gepostuleer tussen thyroxien, cortien, insulien en Vitamin B.

Summary.

Rats kept on a balanced diet with standard Vitamin B content show marked hypertrophy of the suprarenal cortex when subjected to physical exercise. Thyroidectomised rats do not show this hypertrophy under the same experimental conditions. Thyroidectomy without exercise produces a slight atrophy of the suprarenal cortex, whereas thyroid-feeding has the same effect as exercise, viz., marked hypertrophy of the suprarenal cortex.

From the experimental results and the literature, a definite correlation is postulated between thyroxine, insulin, cortin and Vitamin B, all of which are closely associated with the phenomenon of muscular contraction.

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ORNITHOLOGY IN SOUTH AFRICA

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WOOL RESEARCH IN SOUTH AFRICA

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ABSTRACT.

South Africa has specialised in the production of merino wool and to-day she ranks as one of the largest suppliers in international trade.

This industry has grown from a modest beginning in the nineteenth century into a business with vested interests of a 160 million pounds and many thousands of farmers earn their livelihood from this type of farming.

The specialisation of merino wool farming has been built up and developed by the practical man's experience and perseverance and, unlike other textiles, such as synthetic fibres and cotton, the development of wool production has not been associated to any great extent with laboratory research.

An industry connected with such wide interests as breeding, nutrition, environment and general husbandry, in relation to the production of wool, offers an almost unlimited scope for scientific investigation, yet, strangely enough, little laboratory research has, until recently, been undertaken by wool producing countries.

Before researches on wool production could be undertaken, methods of analysing wool had to be placed on a sound basis, and the beginning of wool research had to be devoted to the evolution of these.

There are over fifty characteristics of a physical and chemical nature of the merino fleece, which are of value to the wool farmer, to the wool manufacturer and to the consumer of wool in the finished clothing. Many of these characteristics can now be analysed in the laboratory and, since methods used in studies of wool production often differ from those used in the laboratories of wool manufacturing countries, the methods used in South Africa are devised for studying the merino fleece as a unit of production in association with the animal. It was also necessary that methods were such that they allowed of arithmetic expression.

FLEECE CHARACTERISTICS.

The fibre fineness, referring to the thickness of the fibre, forms a basis for grading wool in commercial practice. The advantages possessed by the microscope projection method have resulted in

the development of a specially designed " Lanameter." The technique of sampling and the preparation of the slides for measurement have been improved upon so that the method is now used in routine laboratory work.

The fleece density, referring to the compactness of fibre growth, depends partly on the number of fibres growing per unit area of skin. Different methods for its determination have been evolved. (Botha 1931; Bosman 1934; Carter 1939).

Fleece density and fibre fineness, together with the factors of fibre length and skin area of the sheep, control the amount of clean wool produced by the animal and the inter-relationships of these characteristics were described (Bosman, 1933). Direct methods of determining the clean weight of the fleece are also used in genetic, nutritional and other experiments with merino sheep and in the recently established service for merino stud breeders (Bosman, 1936).

The breaking strength and tensile strength of wool is conveniently measured (under controlled conditions of humidity) by the apparatus devised by Doehner (1932). It gives an average breaking strength of several hundred fibres from a sample or fleece.

The characteristic of resilience, also known as " loftiness " or " springiness," is a desirable one and is highly valued by manufacturers. Among the methods and apparatus described by research workers (Winson, 1932; Herzog, 1936; Sommer, 1936; et alia), those devised by Henning (1936) have been found most suitable, the technique of sampling and calculation being further described by van Wyk (1939).

The ability of wool fibres to resist constant bending action has an important bearing on the durability of wool clothing. Its measurement has been successfully undertaken by a machine devised by Franz and Henning (1936).

Suitable methods have also been devised for determining the hygroscopicity of wool, the heat of wetting and the specific gravity.

The felting property of wool is associated with the friction set up by the surface scales of the fibres. This friction is conveniently measured as coefficient of friction of the fibres against a standard cloth (Bosman and van Wyk, 1939).

The degree of whiteness is measured by the apparatus of Henning (1935). Laboratory methods have also been devised for determining such characteristics as fibre contour, elasticity, kemp, hairiness, crimping, grease, suint, sand, vegetable matter, yield, cystine content and others.

With these methods available for analysing wool, investigational work into problems of the South African wool industry has been undertaken by the Department of Agriculture and Forestry, assisted financially out of wool levy funds by the South African Wool Council.

THE BASIC CHARACTERISTICS OF SOUTH AFRICAN MERINO WOOL.

With the advancement of synthetic fibres and the greater attention that has been paid to wool propaganda, merino wool interests have come to realise that very little experimental data have been available dealing with the basic characteristics of this product. The Wool Council therefore financed such a project, the results of which are as follows:

The South African wool clip is extremely fine fibred, the average of the clip measuring 19 microns (or a 66's quality number). Sixty per cent. of the clip ranges from a 64's to an 80's quality number. A portion of the clip is even finer than an 80's. These facts have also shown the suitability of South African merino wool for fine fibred woollen materials such as are at present in favour for women's wear.

The average breaking strength of South African wool is 5 6 grams per fibre; the average tensile strength being 1·258 x 10^6 grams per square centimetre, or 8 tons per square inch, of fibre (at 70 per cent. relative humidity and 70°F.).

As regards hygroscopicity, merino wool can absorb up to 27·6 per cent. of its own weight of moisture at 98 per cent. relative humidity.

Merino wool is highly elastic, and can extend to 70 per cent. of its own length and then return to the original, a virtue affecting the smartness of clothing.

As regards resilience, values for South African wool range from 2·5 to 5 kilogramme-centimetre (energy necessary for compressing 5 grams of wool by 50 per cent.). The specific gravity of the product varies from 1·296 to 1·313 (compared with water at 4°C).

South African wool has a well developed felting property, its coefficient of friction ranging from 30 per cent. to 90 per cent. with an average of 65 per cent.

Chemical tests have shown the product to consist of from 10 8 to 12·7 per cent. of cystine, there being no relationships to the physical attributes except to that of resilience.

Merino wool is extremely durable and can be bent backwards and forwards for half a million to two million times before breaking. Certain fibres have stood the test for from 7 to 9 million bendings. Similar tests on cotton and synthetic fibres have given values of from one hundred to two thousand bendings.

THE GENETICS OF THE MERINO.

Although a great deal of research on animal breeding has already been undertaken, little information on the breeding of the merino sheep is available.

Such work has now been commenced and is largely concerned with the inheritance of the fleece characteristics. It has been shown that such factors as the amount of clean wool pro-

duced by a merino, the rate of growth of the wool fibre, the fleece density and the fibre uniformity are genetic factors. It was also shown that fibre uniformity can be influenced by methods of breeding.

Extreme hairiness in the merino lamb characterises the fleece of the adult. Genetic studies on the conformational and constitutional characteristics of the merino are also in progress as well as the correlations of merino characteristics.

The topic of the plain bodied and developed merino sheep is being studied and certain fundamentals, as they affect merino practice, demonstrated. It was shown that the same standard of excellence is possible in both types of sheep, and this conclusion also held in the f 1 generation.

Nutrition and Wool Production.

Wool is extremely sensitive to the plane of nutrition of the animal, and the conditions of South African pastures influence the quantity and quality of the wool clip. Experimental animals have produced 30 per cent. less wool by a lowered plane of nutrition and a fleece of a 64's quality number was refined to one of an 80's quality number. Length, tensile strength, etc., were also affected.

Work on deficiencies of South African pastures in relation to wool production has shown a definite refining of the wool fibre grown under poor winter conditions. A phosphorus deficient diet reduces the quantity and quality of the fleece. Iodine deficient rations do not affect the wool growth, and this has a bearing on iodine containing sheep licks.

The advancement of research must necessarily place merino wool production on a sounder basis than it has been in the past, and at the same time increase the efficiency of production. With the rapid advancement of synthetic textiles which owe their progress to large-scale laboratory research, more investigational work on wool production has become essential. The work now projected shows promise of furthering the science of wool production to an even greater extent than in the past.

Summary.

The specialisation of merino wool production in South Africa and the development of wool research is discussed. Methods of analysing the characteristics of the merino fleece, such as fibre fineness, fleece density, tensile strength, hygroscopicity, elasticity, resiliance, specific gravity, coefficient of friction, chemical composition and resistance to bending are outlined, and the results obtained on South African wool, summarised.

The progress in the studies of merino genetics and the nutritional influences on wool production are discussed.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVI, pp. 436-437, December, 1939.*

SHORT PERIODS OF PRODUCTION AS CRITERIA FOR PREDICTING ANNUAL EGG PRODUCTION

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ABSTRACT.

The breeding for increased egg production has resulted in an accumulation of numerous production records on poultry farms. Breeders have become more interested in trapnest and pedigree records. They no longer select good layers on body characters only. In recent years various short periods of production have been determined which are considered as a reliable estimate of annual egg production.

In 1932 the author presented results of 305 closely related White Leghorn hens, and he found that annual egg production could be predicted fairly accurately from the winter or summer-autumn period of production.

In the present study prediction formulae were determined from the old and revised formula. Prediction formulae were secured for different short periods of production as:—

Periods of Production.	Prediction Formula.
Winter	$y = 1{\cdot}215x + 143{\cdot}011$
Spring	$y = {\cdot}74x + 148{\cdot}2267$
Summer-Autumn	$y = 1{\cdot}074x + 134\ 89$
May, June, July and January	$y \quad {\cdot}93x + 159\ 9$
May, June, July, August and April ...	$y = {\cdot}96x + 145{\cdot}33$

In the application of the above prediction formulae to known production records the following results were secured. In each case the actual production of one hen is used as an illustration:—

Periods of Production.	No. of Eggs for Period.	Actual Annual Production.	Predicted Annual Production.
Winter - - - - - - -	50	205	203·76
Spring - - - - - - -	88	217	213·35
Summer-Autumn - - - - -	80	224	220·81
May, June, July and January - -	72	224	226·86
May, June, July, August and April -	86	229	227·89

The predicted annual production is secured as follows, when a hen produced 50 eggs during May, June, July, August, the winter period and the prediction formula is:

$$\begin{aligned} y &= 1{\cdot}215x + 143{\cdot}011 \\ &\quad (1{\cdot}215x)\ (50) + 143{\cdot}011 \\ &= 60{\cdot}75 + 143{\cdot}011 \\ &= 203{\cdot}76 \end{aligned}$$

In this case it is evident that if a hen laid 50 eggs during the winter period, she should approximately lay 200 eggs during the year.

The same procedure is adopted if it is decided to predict annual egg production from other short periods of production. The prediction formula for May, June, July and August and April production the following year is given as:—

$$y = {\cdot}96x + 145\ 33$$

If a hen laid 86 eggs during this period, then her production is predicted as $({\cdot}96x)\ (86) + 145{\cdot}33 = 227{\cdot}89$. This figure corresponds very closely with the actual trapnest record of 229 eggs. The winter period plus April production is a most reliable record for annual egg prediction.

Egg prediction could also be applied to the records of a group of hens. Twenty White Leghorn hens laid 1,189 eggs during May, June, July and August. By applying the prediction method (y $1{\cdot}215x + 143{\cdot}011$), they should theoretically lay $(1{\cdot}215x)$ $(1{,}189) + (143{\cdot}011 \times 20) = 4{,}330{\cdot}657$ eggs per year. Actually these birds laid 4,214 eggs per year. This is an error in prediction of 2·8 per cent. or 5·8 eggs per bird. The error in prediction might be due to numerous factors such as care, management, housing, feeding and breeding.

If 20 hens laid 1,567 eggs during May, June, July, August plus April, the following year (the prediction formula being $y = 96x + 145{\cdot}33$ for this period) they should theoretically lay $({\cdot}96x)\ (1{,}567) + (145{\cdot}33 \times 20) = 4{,}410{\cdot}92$ eggs. Actually they laid 4,461 eggs. This is an error of 1·12 per cent. or 2·5 eggs per bird.

The prediction method of judging productive capacity of a hen should be of great assistance to poultrymen who do not wish to keep detailed production data. It will also save considerable time and labour if trapnesting could be done during a short period which will give sufficient indication of the poor and good producers.

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SOME ECOLOGICAL METHODS IN RESEARCH ON BUBONIC PLAGUE

BY

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1. Introduction.

Since the intensive researches on the bacteriology and parasitology of plague in rodents in South Africa by Mitchell, Pirie and Ingram (1927), research work has been confined to laboratory investigations of plague bacteriology at the S.A. Institute for Medical Research and to observations made by officers and rodent inspectors of the Health Department in surveys and in dealing with outbreaks. Two papers by Fourie (1936, 1938) describe some aspects of the epidemiology of plague in wild and domestic rodents. These researches form the basis for intensive ecological investigations which were started in an endemic plague area at Holfontein in the Kroonstad district, O.F.S.

A base camp was established at Holfontein last September (1938) and has since been the centre of activities. Up to the present, attention has been given to veld and domestic rodents and their respective fleas; field work on plague has been negligible owing to the almost complete absence of epizootics in the area during the period. Experimental work on plague is planned, but has not yet begun.

The work is designed to confirm previous findings and to explore further the problems still awaiting solution, in order to provide a foundation for devising further scientific measures to prevent man's infection.

2. The Present Situation.

Plague is a disease of rodents, and it is only by the accident of contact with infective fleas from rodents that have died of plague that man becomes infected. The causative organism, the bacillus ***Pasteurella pestis***, which is spread by the bites of infective fleas, survives in the rodent population forming a permanent reservoir of enzootic infection. Plague is now enzootic in the rodent population over a large area of Southern Africa. Human cases of plague, reflecting the minimum area of the distribution of plague in rodents, have occurred during the last

twenty years in parts of the eastern and north-western Cape Province, the Orange Free State and borders of Basutoland, the southern and western Transvaal, Bechuanaland, South-West Africa and Angola. Circumstantial evidence suggests (Fourie, 1938), that spread across the Basutoland border has taken place not only from infected ports, but also from a number of points inland during the early years of the century. During recent years only has plague spread north-westwards from the Union to the adjacent territories of South-West Africa and thence to Angola, and into Bechuanaland towards the border of Southern Rhodesia.

Sporadic cases now occur annually in widely separated parts of the Union, but chiefly in the Free State, eastern Cape and south western Transvaal. For the most part these outbreaks occur at a time when the density of the veld rodent population has reached a peak in numbers and is being reduced by epizootics of plague. Fourie (1938) has shown that since 1920, in the Free State gerbilles have increased to a peak every three to five years, and that extensive outbreaks in man have followed the rodent epizootics. Why human cases are so sporadic remains a mystery, but, as Fourie (1936) has pointed out, there is evidence to suggest " . . . that the very infrequent occurrence of human cases is due . . . to some unknown weakness in the link formed by the flea." Man has become infected in the veld, but such cases are rare. The most usual source is either from the multimammate mouse *Mastomys coucha* which is equally at home in the veld as in domestic premises (thus forming a link between the veld and man's habitation for the carriage of fleas) and the house rat (*Rattus rattus*) which, though predominantly an occupant of buildings occasionally lives away from these where suitable harbourage such as other rodent burrows, walls, aloe hedges, etc., are found.

Up till recently *Mastomys* has been the main source of infection. Lately *Rattus rattus*, particularly in the Free State, has been the source to man and on some occasions has died in numbers without any traceable infection in the veld rodents. Thus it seems that, together with *Mastomys*, *Rattus rattus* is forming a reservoir of plague independent of gerbilles in the veld, so making the situation potentially more dangerous than in the past, and further complicating the problem.

The problem is thus clearly an ecological one, depending for its solution on a complete understanding of the interrelations between the plague bacillus, the rodent and flea population and factors of the environment. An analysis of the interaction of these components should give us a picture of the course of events leadings to man's infection.

3. Aims and Some Methods of Research.

The aim of the preliminary field work is to work out standard quantitative methods of collecting data and of observation in the field on the rodents and fleas in the Holfontein area. The

results of intensive work in one small area are to serve as a standard of comparison with conditions in other parts of the country. In what follows reference is made only to what has been found in the Holfontein area.

(a) *Gerbille Population Studies.*

Gerbilles (*Tatera brantsi*) are colonial, vegetarian, nocturnal, burrowing rodents, living in warrens which vary in extent, but are made up of a number of separate groups of interconnecting underground runs. Warrens are widely distributed, but are usually several hundred yards apart, often more. They are found in old lands, wheatlands, pasture, but not in growing maize, near farms and native huts, especially in maize threshing floors. The burrows are about two inches in diameter and go down to a depth of 1ft. 3in. to 2ft. though deeper ones are known. A hollowing out of the burrow several feet from an entrance hole holds a nest. Each burrow system (in which the underground runs interconnect) is entered by 2 to 10 or more holes.

An occupied warren presents a typical appearance. A small mound or streak of soil lies at the entrance of most burrows. Loose soil in the burrow is pushed to the entrance during the night and kicked out, so that fresh soil at the entrance indicates gerbille activity. In quantitative work the presence of freshly thrown out earth at a burrow mouth is taken as the unit of activity for measuring the amount of activity of the gerbilles. It has been found as a result of trapping experiments that there are between 5 and 10 active burrows in a warren to each gerbille. Further investigation is still needed before counts of active burrows can be used to indicate the number of gerbilles in a warren, particularly as habits vary in different soils and situations. Active burrow counts of one warren or a series enable us to follow the history of the occupants with some accuracy. As increase shows, for instance, that young are being born or that there has been imigration and similarly a decrease that there has been emigration or dying off from disease. For regular observation it has been found best to mark out the warren with pegs at 6ft. intervals in the form of a grid, so that each 6ft. square on the grid can be identified by a letter-number. By following each monthly count of active burrows by live trapping, marking and releasing the gerbilles, a detailed history of the population would be obtained. Live trapping and marking methods have now been perfected so that such experiments will proceed on more detailed lines.

Such lines of enquiry contribute to one side of an attemt to reach an understanding of the dynamics of the gerbille population. They give us information on the rate of growth in nature of populations and on the amount of local movement in response to changes in the environment. In addition to following the history of live animals, monthly quotas of trapped gerbilles are examined for their reproductive state, age and other points. From

these data the potential rate of increase of gerbilles can be worked out when supplemented by experimental breeding to determine such points as the rate of growth, length and expectation of life, fecundity, etc. Together these different methods of approach are designed to show the rate at which a gerbille population increases and provide us with a means of relating outbreak of epizootic disease with a certain density of population.

(b) *Flea Population Studies.*

For the purpose of this paper I shall deal only with fleas of gerbilles (*Tatera brantsi*) and of house rats (*Rattus rattus*). The data on multimammate mice (*Mastomys coucha*) are not enough to justify any statement yet.

There are four chief species of fleas: *Dinopsyllus ellobius ellobius*, *Xenopsylla eridos* and *Chiastopsylla rossi* on gerbilles; and *Xenopsylla brasiliensis* on rats. All have been proved to suck human blood and to transmit plague (Ingram 1927). Except for *C. rossi*, each species has been found on rats and gerbilles. But it is only in rare instances that gerbille fleas have been found on rats and vice-versa. Nevertheless, the link is there between veld and habitation.

Flea numbers are controlled mainly by the climatic conditions under which they have to live. If flea larvae are exposed to dry air they perish rapidly: but if they are kept in moist air they survive. Temperature also plays a part as it affects the rate of development of larvae and hence the turnover of fleas. A seasonal fluctuation brought about by seasonal changes in the burrows and places where fleas breed is therefore to be expected, and this is so, but owing to the different characteristics of the different species there is also a fluctuation in their relative abundance. Ingram (1927) working in the northern Free State found indications that *C. rossi* was almost absent during the latter part of the summer, but became most numerous during the winter, replacing to some extent *X. eridos*, which was most abundant in the summer. *Dinopsyllus ellobius* remained more or less constant except at the end of winter and beginning of summer, when its numbers were lower. These findings are confirmed by the results from Holfontein, as far as they go.

In plague investigations it is customary to express the degree of parasitism by fleas as the average number of fleas per rat examined (the flea-index). In many ways this is a useful and simple way of expressing an important epidemiological fact, but it gives us no numerical idea of the state of the flea population in the rats' habitat. No attempt has ever been made to relate this small sample to the total population owing to the difficulty of estimation. Gerbilles, since they live in a closed burrow system provide us with excellent facilities for such a study, for, by collecting all the fleas living in each separate burrow system of a warren, we can get the total numbers and relate them to the numbers actually found in the gerbilles inhabiting that warren.

It follows that if there is a constant relation, then the flea-index will provide us alone with an estimate of the whole flea population.

A census of fleas in a burrow system is carried out in this way. A group of burrows, to all appearances forming part of one system is marked out with a peg to each burrow entrance. With a little preliminary excavation to allow a suitably shaped tool into the burrow the loose soil lying at the bottom of the burrow for one foot from the entrance is removed and kept in a numbered bag. The operation is repeated for all other entrance holes. A peg placed a foot from the entrance marks the point from which the second sample is to be taken. The first foot is dug away, the sample taken, and so on until the whole system has been excavated. The location of each sample, and the depth of the burrow, is marked on a plan to scale as the work proceeds, and the location of nests and other points are recorded. Each sample is subsequently sifted through a mosquito gauze sieve over a large tin basin and the fleas are collected as they jump to the edge. The debris from the samples is kept in a petrol tin until any eggs, larvae or cocoons in the sample have had time to develop and hatch out. Thus we also know the productive capacity of the burrow at that time.

X. brasiliensis, the house rat flea, breeds in the loose debris, dust and rubbish that clutter the outbuildings of the average farm. Even where there are cement floors, fleas are found, Here, it is clearly not so simple to collect every scrap of dust that might harbour fleas, and no attempt has yet been made to examine more than samples. But these have in some cases produced several hundred fleas and as many larvae from a few handfuls. In such places rats have a very high flea-index, as would be expected.

(c) *Microclimatic Studies.*

The importance of climate to fleas has already been mentioned. Gerbille burrows usually run down to a depth of 1ft. to 2ft. below the surface. The soil retains moisture and heat, and keeps the air in the inner parts of the burrows at a more or less steady temperature and humidity which varies only with the seasons. Gerbille burrows thus provide a climate in which fleas may pass their life history at all times of year, without undue mortality. Field observation has shown that in natural gerbille burrows the temperature remains nearly constant day and night, and that the saturation deficiency of the air is low or nil. A limited number of such observations has been made only, but they have been confirmed by readings taken in an artificial burrow. A straight pipe of ½in. wire netting, 18 feet long was sunk in a trench so that it inclined from both ends at the surface to a point 2 feet below the ground in the centre. At three foot intervals a tube for a thermometer and a tube for taking air samples were so placed that the records taken indicate the con-

ditions at that point of the burrow. Thermometers embedded in paraffin wax in a glass tube, left at each of five points (two at 9 inches, two at 1ft. 3in., and one in the centre at 2ft.) are read daily. The humidity is determined by obtaining the dew-point in a Casella Dew Point Apparatus, but the results have not been entirely satisfactory. Daily records of temperature have been kept from the end of May. There has been a slight drop in temperature in the centre from 60°F. on 24th May, to 55°F. on 24th June, but no diurnal variation. Earth temperatures are now being taken at the same depths and they closely parallel conditions in the burrow.

Caves are noted for their extremely constant climates. A glance at earth temperature records also shows great constancy below a foot or two. These facts and experience with natural and artificial burrow climates suggested the idea of an artificial cave where experimental work could be done under conditions similar to those in nature. A small pit was therefore dug and roofed in and was found to provide conditions fairly similar to those in burrows and fleas were successfully reared. Later a larger pit 6 feet deep with a trench entering it was dug and roofed over with corrugated iron which was covered with the excavated earth. A door closed the chamber from the trench, which was also covered for some of its length. In here the temperature and humidity remained absolutely constant day and night, almost exactly corresponding to the records taken at the 2ft. depth in the artificial burrow. Stocks of the different species of fleas are now being raised in the chamber. Experiments with populations of the different species are planned to compare with field observations when a supply of newly hatched fleas is available.

4. Acknowledgements.

I have pleasure in thanking Dr. L. Fourie for his help and suggestions in planning these researches. Dr. de Meillon, of the S.A Institute for Medical Research, who is collaborating in the parasitological and climatological investigations, receives my special thanks. I wish to thank the Director and the staff of the Meteorological Department for practical suggestions and for the loan of instruments. Finally, I am indebted to the Secretary for Public Health for permission to present this paper.

5. Summary.

(1) A brief outline of the salient points of the present situation of plague in man and rodents in South Africa is given Attention is again drawn to the increasing importance of *Rattus rattus* as a primary reservoir of plague in the northern Orange Free State.

(2) The methods being developed in studying the dynamics of gerbille (*Tatera brantsi*) populations in the Holfontein area, O.F.S., are outlined. Regular observations on warrens, combined with marking experiments and a knowledge from field observa-

tions and experiment of gerbille reproduction form the basis for this study. It is particularly important in determining the exact point at which, in the population's growth, plague and other epizootics break out.

(3) The fleas (of the Holfontein area) *Dinopsyllus ellobius ellobius*, *Xenopsylla eridos* and *Chiastopsylla rossi* are those commonly found on gerbilles; while *X. brasiliensis* is found on rats (*Rattus rattus*). In rare instances have gerbille fleas been found on rats and vice versa. A method is described whereby total counts of fleas are made in gerbille burrows. The relation of the flea-index on gerbilles to total fleas dependent on the gerbilles can thus be determined.

(4) A description is given of an underground chamber where climatic conditions closely parallel those in nature in gerbille burrows and where fleas can be thus studied in their natural climatic environment.

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THE ESTIMATION OF THE AGE OF MERINO FOETUSES

BY

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Read 7 July, 1939

ABSTRACT.

The data upon which this study is based consist of the weights and twelve linear measurements of a series of thirty-three accurately aged merino foetuses. After detailed consideration of cumulative growth-curves, relative growth-rates and correlation coefficients, it is indicated how these may be used for the estimation of foetal age. Finally, these data are employed in the construction of a simple normograph from which age may be read with considerable accuracy.

The complete paper is in the process of being published in the *Onderstepoort Journal of Veterinary Science and Animal Industry*, Vol. 13, No. 2.

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THE ORIGINS OF CERTAIN AFRICAN FOOD-PLANTS

BY

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The ethnologist is interested in the methods of dispersal of zoological and botanical species; the distribution of plant and animal types and their functions in economic relation to man.

To the ethnologist the most important channel has been the distribution of plant and animal forms by man during the later Stone Age and through the subsequent Metal Ages. This distribution has been for the most part wilful and intentional. But it has been controlled and guided by the presence or absence of suitable environments, and by the presence or absence of suitable routes between human groups.

The development of any concentration of mankind is based directly upon man's ability to use plants and animals. The concept of domestication, whether of animals or plants or both, is essential for the growth of any town system, and as essential to the adoption of a stable mode of life with its associated accumulation of property. Cultivable plants with a high yield of transportable and preservable food are essential to the growth of a stable civilisation, however simple. The security given to man's economic system by crops distributable over a wide area, and foods available throughout the whole year, is a primary necessity before any focus of human population can develop.

It thus becomes important in studying the history of mankind to seek the origins of cultivable plants and domestic animals which have provided this foundation for man's development. The researches undertaken at Onderstepoort and elsewhere have so far been ignored by the ethnologist. Various members of the staff of that institution have made valuable contributions to our knowledge of the origins of African domesticated animals. Similarly little use seems to have been made outside Europe of the analogous botanical research, first undertaken by A. de Candolle (1) and since augmented by N. I. Vavilov (2) and others.

De Candolle based his work mainly upon the apparent relationship between domesticated forms and their nearest spontaneous relatives. Recently, some remarkable ethno-botanical research has been carried out under the direction of Vavilov from

Russia (3). Much of this work is not obtainable in South Africa, and we are therefore obliged to turn to summaries of his work (2, 4) for much of the material quoted. In recent years work (mainly on grasses) has been done by writers such as Hill (5), Arber (6), Peake (7), and others.

Vavilov bases his assumptions as to the origins of domesticated plants upon the hypotheses expressed by Willis (8). Briefly, Willis states that in comparing wild species of plants, which have similar modes of dispersal, those with the wider distribution may be accepted as the older. In addition, the longer a given species has been established in a given area, the more diverse will be the species or sub-species found there. From these two rules of thumb Vavilov takes the centre of dispersal as coinciding with that area which shows the greatest variety of spontaneous, undomesticated species. This method is probably as good as that employed by de Candolle, and the results necessarily coincide in many cases. Where Vavilov has made his real advance is in his search for and discovery of vast numbers of spontaneous species and variations allied to domesticated plants known to man and used by him. The material at his disposal is therefore far greater than that used by de Candolle.

Certain factors need watching. An early genus or species may have a distribution so wide that its original home is undiscoverable. A species once consistent in its distribution may have had its original area divided by climatic changes (glaciation or dessication). or by the rifting of valleys. the folding of mountains, or even by continental shifts. For instance, it is more than likely that the drying up of the Sahara has split and separated one great ecological region of winter rainfall into two or even three isolated sub-regions. Gautier (9) and others have touched on the fringes of this problem, and have shown that isolated remnants of a single widespread flora and fauna are to be found to-day associated with cases and distributed in fertile marginal areas about the Sahara. In cases such as these it must be left to the botanist to develop the most suitable hypothesis as to the original centre of dispersal.

As it has little bearing upon African food plants, we may ignore Vavilov's work on the origins of such grains as wheat, barley, rye and so on, and concentrate upon his results as they apply to our own continent. The main results of his work show that the primary agricultural centres of the world are confined to the tropical and sub-tropical regions, and are associable with mountains or highlands. Seven such centres are described. The five in the Old World are associated with the Himalayas, the Hindu Kush, the mountains of Ethiopia, the highlands about the Mediterranean, and the mountainous regions of China. The two New World centres are confined to the tropical Andes.

1. *South-western Asia.*—This centre includes the interior of Asia Minor, Afghanistan, Turkestan and north-western India, the home of the soft wheats, rye, flax, alphalpha, Persian clover,

the apple, the pear, pomegranate, quince, sweet cherry and the grape, besides many vegetables, and those plums grouped under the name *Prunus divaricata*.

2. *India Proper.*—A region covering the Hindostan peninsula and the Ganges valley, the original home of rice (still the staple food of more than half mankind), commercial sugar-cane, the Asiatic cottons, the mango and other tropical fruit trees.

3. *China.*—This centre is confined to the eastern and central mountains of China, including the upper courses of the Hun-ho and Yangtse-kiang, and yielded the cabbage, radish, Citrus fruits, peach, Chinese plums (*Prunus Simoni*), the tea-shrub and the mulberry tree.

4. *Mediterranean.*—This embraces the ancient countries of Europe, including the Iberian, Apennine and Balkan highlands, the coastal parts of Asia Minor, Egypt and the Nile, with the winter rainfall area of Palestine and North Africa, and yielded the olive, the leguminous carob tree, the fig, lens, and a few forage plants.

5. *Ethiopia.*—The mountains of Abyssinia and the eastern sources of the Nile. Vavilov regards this as unexpectedly important, more especially as it was accessible to the ancient Egyptian civilisation. Certain wheats, barley, sorghum and coffee originated here, together with such crops as teff, flax and so on.

6. *South Mexico*, including part of Central America. Maize, Upland cotton, cacao, the agave, certain musky pumpkins, beans, pawpaws and other less valuable crops hail from here.

7. *Peru* and *Bolivia* have provided the potato, the chinchona tree, the coca shrub and soft maize.

The intimate relationship existing between these areas and highlands is explained by Vavilov, who suggests that the folding and rifting of mountain areas favoured the segregation of plants, and the ultimate development of new varieties and species.

If we take climatic history into consideration, it is perfectly possible that regions 1, 4 and 5 represent the isolated extremes of one great ecological area, subsequently cut into three by the climatic changes associable with the Bühl Stadium. From that point the aridity of the Sahara and the Arabian deserts seems to have increased until the present climatic conditions appeared. This would account for the wide distribution of the important wheats.

African Foods.

In seeking the origins of those foods which have, for varying periods, been fundamental to the African economy, the evidence of the botanist has been sought. Unhappily botanists disagree in many cases. If two alternatives are known, and if neither has precedence, both possible sources of the food are given, pending the collection of further botanical data. It is to be hoped

that further evidence, resting upon a wider basis of collected material, will be obtained concerning domesticated plants. Peculiarly enough, one hiatus in detailed evidence appears to be the group of native sugar-canes, which has been somewhat neglected by the botanists of this country.

The only writer on Africa who has attempted any record of his ethno-botanical opinions is Sir Harry Johnston (10), but a clearer and more comprehensive analysis of the history of African domesticated plants would prove exceedingly useful to the ethnologist. Johnston is insufficiently exact, and much more light is needed on useful plants employed, though not necessarily cultivated, in Africa. Toxic and medicinal material have been efficiently studied by various writers, but much remains to be done on cordage, bark-cloths, plant fibres generally, dye-producing plants, tannins and so forth.

"Down to the end of the fifteenth century," says Johnston* "the indigenous foodstuffs of the Congo basin must have been limited to the banana, the coco-yam (a Colocasia aroid), the *Dioscorea* yam, and among grains possibly millets (*Panicum frumentaceum*, *P. sarmentosum*, *P. maximum*, *P. spectabile*, *P. Burgu*, and *Pennisetum typhoideum*). Sorghum (*Andropogon*) and *Eleusine*, another millet-like grain. Even the cultivation of the millets (*Panicum* and *Pennisctum*), eleusine and sorghum —all these grasses except *Panicum* are not indigenous to tropical Africa—probably did not exist in the central basin of the Congo."

"The Negroes . . obtained an abundance of sweet, palatable and nutritious sap of the oil palm, the raphia and the borassus."

"There is a kind of wild rice, *Zizania*, of poor quality, apparently indigenous to the rivers of the northern (Congo) territories."

It will be seen later that many of these domesticated plants had origins quite other than those suggested by Johnston. Indeed it is uncertain whether the wild African rice is *Zizania* or *Oryza*, and evidence suggests that it is more probably the latter.

Gramineae.

Sorghum vulgare Pers. (*Andropogon sorghum* Brot. or *Holcus sorghum* L.).

Cultivated over a large part of equatorial and sub-equatorial Africa. It is known generally as Durra, with a variety of spellings. According to Hill (5) it seems to have been domesticated in very early times, and was grown in Egypt prior to 2200 B.C. It was grown early in India and China, and in all these countries is still an important crop. De Candolle (1. p. 306), after discussing the Chinese origin for the cultivated plant, says "It is easier to understand it as native to equatorial Africa with a prehistoric migration to Egypt, later to India and finally to

* *George Grenfell and Congo*, pp. 600-601.

China, where its cultivation does not seem to be ancient." Dr. Pole-Evans (11) states that the American stocks came from Africa. "In 1853 Wray collected sixteen varieties for the United States Department of Agriculture. These came from Natal. Africa is undoubtedly the home of this group, but records show that in China, too, *sorghums* were grown for human consumption as early as 2200 B.C." This dating for the Chinese use of *sorghum* is in strange accord with Hill's dating for Egypt, and one or other writer appears to have misquoted an original source. Hill is in closer accord with de Candolle.

Vavilov's African expeditions confirm the view as to the probable African origin. He states (2. p. 102) of Abyssinia that "here we find the maximum diversity in the world so far as the varieties of wheat, barley and perhaps also the grain *sorghum* are concerned."

The grain is less nutritious than maize, but constitutes the staple food over a large part of Africa, a region only decreased by the spread of maize in suitable environments. Thomas and Scott (12) find it as supplementary to *eleusine* in Uganda, where it is now a crop grown solely to produce a fermenting agent in beer. The Shilluk obtain a red dye from the boiled stems of the plant (13).

Sorghum vulgare Pers, var. *saccharatus* Korn.

While the small grain is of little practical value, the stalk provides an excellent sweet syrup, much used by the south-eastern Bantu, to whom it is generally known as *imFe*. The original American stock came from Natal, and the juice, which does not crystallise easily, is commercialised in a form similar to that of maple syrup. It is certainly South African in origin, a fact increasing the probability in favour of an African origin for the other types of *sorghum*.

Other Varieties.

The validity of many varieties of *sorghum* is uncertain, and there would appear to be a number of disconcerting synonyms involved. *Sorghum vulgare*, var. *caffrorum* Retz, or Kaffir-corn, Hill regards as a native of tropical Africa, whence it has spread all over the world. *S. vulgare*, var. *subglabrescens* Steud. he places as African, while the variety *caudatum* Hack. (or feterita) he regards as of Sudanic origin.

Panicum maximum Jaq.

De Candolle seems to regard this as having a possible domestic origin in the Antilles. He continues (pp. 92-93) "In conclusion there is a slightly greater possibility in favour of the African origin, conforming to the indication of the common name (Guinea grass), and to the general, though not profound, opinions of authors. Nevertheless, when a plant spreads so easily it seems singular that it should not have spread from either Abyssinia or from Moçambique to Egypt, and that it should have been so

lately received in the East African islands." He gives a wide African distribution for related species and varieties, Sierra Leone, and other West African sites, the Cape Province, Ethiopia, Moçambique, the Zambesi, etc. It should be borne in mind that the genus *Panicum* is spread as a spontaneous grass in all tropical and sub-tropical regions of the world.

Panicum miliaceum L.

True millet was prehistoric in Europe, where it was the *milium* of the Romans. It was used by the Swiss lake-dwellers, and was an early grain in Asia. The early Egyptian use of this grain appears somewhat uncertain.

Echinochloa stagnina P. Beauv. (*Panicum Burgu*, A. Cheval).

This sugar-yielding cane, grown north of the Ubanghi, and other varieties of *Panicum* are almost certainly Asiatic in origin.

Pennisetum typhoides Stapf and Hubbard.

Is generally known as Pearl or Bulrush millet. Arber (6) is the only writer besides Johnston to take note of this " millet " in Africa. Bews (14) merely states that " *Andropogon* and others are mixed with *Pennisetum* in the high grass savanna of Central Africa " (p. 87). The variety of synonyms applied to this species is almost infinite, and may be sought in Chase (15). In Africa the traveller Barth noticed that the Tagama tribe used a wild *Pennisetum*. The seeds were collected and pounded by the slaves. The grain is cultivated over the whole continent of Africa, and has spread to Arabia, Afghanistan, parts of India and to the West Indies. Arber (p. 25) ends with an interesting statement, " It has been suggested that Pearl-millet may have arisen polyphyletically from a number of wild forms, native to tropical Africa. If this theory is sound, the plant would be an interesting subject for a thorough genetic analysis."

Eleusine coracana Gaèrtn.

Resembling the millets and often known as ragi or as African millet, it is almost certainly of South Asiatic origin. It is grown from Malaya to northern Africa, but does not seem to have spread far into this continent, though de Préville (16) gives it a considerable area along the upper Ubanghi in Central Africa. He says (pp. 235-236) it is cultivated in Abyssinia under the name of *tsada-agoussa*, or *dakoussa*, for flour at the Royal table. This grain is certainly *Eleusine Tocussa* Fresen., which would seem to have had an Abyssinian origin. The Nubian Arabs despise *Eleusine*, and here it is called *telebun*. The Azandeh grow it in less fertile fields in regions too humid to allow other grains to ripen. It here provides a secondary mode of subsistence, and supplements hunting and collecting. In Uganda (12) many varieties are grown, and the grain is kept stored in the head, lasting in good condition for some five years. The yield is from 900 to 1,800 lbs. per acre under native cultivation.

In many cases it is uncertain whether *E. coracana* or *E. Tocussa* is intended in describing African distributions. It can be accepted that the *E. Tocussa* had an Abyssinian origin as a cultivated plant, while it seems as certain that the more general *E. coracana* had a south Asiatic origin. Arber suggests that this latter probably originated from *E. indica*, L. Gaertn., a grass widely distributed in the Mediterranean, parts of Asia and of America. It was not used by the American aborigines.

Oryza and *Zizania*.

Zizania aquatica L. is spontaneous in America, together with another species. The Indians there tie young bundles of growing rice, wait for it to mature, and beat it into their canoes. They also broadcast seed for the next crop. Otherwise the rice is spontaneous. In Africa only Johnston makes definite use of the name *Zizania*. The traveller Barth records that in Bagirmi where rice was not cultivated, it was easily and freely obtained from the forest swamps, especially after rain. " In Senegal," says Arber (6. p. 37), " the natives use a wild rice which has penetrating rhizomes." Similarly wild rice is spoken of on the Ubanghi, where that river intersects the equator. Both Bews and Arber only mention a spontaneous American distribution for *Zizania*.

Oryza sativa L. is certainly grown, wherever the terrain is suitable, throughout tropical Africa, but it has just as certainly been brought into Africa by Dr. Pogge, the German explorer, and by Arab slave and ivory traders, together with the whole complex of the paddy-field. In spite of this Arber (p. 27) does not exclude Africa as a possible origin. In view of the absence of any record of early paddy-field cultivation with its peculiar system of flood-irrigation in Africa, we may more safely follow Vavilov, and regard it as having originated in India proper as a cultivated foodstuff. While " wild rice " is spoken of as being used by Africans without cultivation, more information is essential before we can ascribe it to either *Oryza* or the less probable *Zizania*.

Zea Mays.

Was introduced into Africa at the Congo mouth in 1560. It is almost certainly Central American. Vavilov regards the soft maizes as Peruvian, and the remainder as Mexican. Arber (6) states that varieties of white, yellow, blue, purple, red and blue grains were grown by the early Mexicans. Indeed, maize was grown from Peru to the centre of North America by the time of Columbus. To-day it is displacing many genera of plants over the bulk of Africa, and is grown wherever climatic conditions allow it to ripen. In its first three hundred years this plant became the staple food of large areas from the Sahara to the Karoo. The speed of its spread is considerable, when we realise that with the distribution of an annual it is essential to await the production of seed for a year at a time. Little more need be

said of this recent crop, save to add that two additional channels of cultivated breeds from America must be remembered, by way of the Union, and secondly by way of the Mediterranean strip. It is one of the few African foods which is being continually bettered by the distribution of highly cultivated stocks.

Root Crops.

Dioscorea sativa L. and *D. Batatas* Decaisne.

While the word "yam" appears to have had an African origin from *igname* or *inhame*, a wide-spread root along the Guinea coast meaning "to eat," the origin of the plant itself is less certain. There are some 200 species scattered through the tropical regions of both Old and New Worlds. In Africa, only a few indigenous yams appear, in south-west Asia many, and in America fewer. There are various cultivated types, in Africa *D. sativa* and *D. Batatas* are cultivated. In New Guinea *D. triloba*, and in the Pacific generally, *D. alata* are the commonest species grown. We may presume, lacking good evidence to the contrary, that the edible *Dioscoreae* were first cultivated in south-eastern Asia.

Manihot utilissima Pohl (*Manihot esculenta* Crantz., *Jatropha manihot* L.).

It would seem that the edible maniocs may be grouped under the name *Manihot esculenta*. Over 150 varieties of this plant have been described, and their distribution points to a South American origin for the cultivated types. To-day most of these varieties are known and cultivated in tropics and subtropics throughout the world. In both Asia and Africa manioc or cassava is a relatively recent food. There are 42 species known from America, and as it was used in Brazil before the Spanish occupation, we can presume its Andean origin.

Both the sweet and the bitter cassavas grow easily from cuttings, and are generally planted with a nitrogenous crop of beans, etc. between the rows. The crop needs heat, moisture and shade, and is therefore an excellent tropical forest belt crop. As the plant is a heavy feeder, new fields are constantly being broken, and villages tend to migrate every three or four years. For the first crop at the new village the African plants bitter manioc, as this can be cropped after ten months. The sweet maniocs need some eighteen months before they ripen. All cassavas contain a high percentage of prussic acid, and in bitter manioc the percentage is high enough to be poisonous. Wherever the root has been introduced, the essential cleansing process must have been imparted to the natives. In Africa generally the bitter manioc is washed, grated, pressed and dried with sun-heat, which is sufficient to drive off the volatile acid. The sweet manioc needs less preparation. A somewhat insipid bread or porridge is made from the tapioca, it has a high food value, comparable with that of wheat.

Ipomoea Batatas Poir (*Batatas edulis* Choisy, or *Convolvulus Batatas* L.).

Was introduced into Africa from Peru, possibly by the Portuguese, though its use in both hemispheres goes back to fairly early times. It is just possible that it was known in Malaya, and reached Africa through Dutch or Portuguese trade with the Malayan archipelago. We may regard it as having originated in tropical America, as it was known to the Incas before the arrival of the Europeans. It must be remembered though, that the *Convolvulaceae* are of the most widespread families in the world, and the possibility of two or more sources must not be forgotten. De Candolle (1. p. 43) states that this plant was used in China as early as the second or third century, A.D., but suggests that this Asiatic plant was probably an allied edible convolvulus which has since been displaced by the sweet potato proper.

Ipomoea digitata. L. is the only unusual species found in Africa. It is grown in West Africa, apparently as a purgative.

Voandzeia subterranea Thou (*Glycine subterranea* L.)

Is of African origin, and is spontaneous in the Upper Nile region. Sir Harry Johnston regards it as an Arabic importation from Madagascar, where it is much used. It seems far more possible that it is African, as no wild forms occur on Madagascar.

Arachis hypogea L.

Is of Brazilian origin, and has long been cultivated there. Six wild species occur in Central America, and the Portuguese introduced it into the Old World. Peculiarly enough, the North American crop originated from domesticated African stock, taken over to Virginia by slaves at a later date.

LEGUMES.

The Ers seems to have provided the only groups of edible beans used in Europe before the discovery of America. These beans were used in prehistoric Egypt, Algeria and south-western Asia. The usual species appear to be all of Mediterranean origin. In Africa are found *Vicia ervilia* Willd. (*Ervum ervilia* L.), *Lens esculenta* Moench., and *Vicia Faba* L. The lentil was introduced early into Greece, Egypt and Palestine, and has a high nutritive value.

Phaseolus vulgaris L.

Originally south Mexican, the Kidney or Haricot bean came to Europe after the discovery of America. It does not seem to have been cultivated long in Africa.

Phaseolus lunatus L. (*P. inamoenus* L.)

Was known neither in ancient Egypt nor in India at any early date. It is to-day widespread in Africa, but judging from remains in pre-Columbian tombs in Peru, it has quite certainly been brought to the Old World from the Andes.

Phaseolus trilobus Ait. and *P. Mungo* L. (P. *aureus* Roxb.).

Are extensively cultivated in Africa to-day, but seem to have had an Indian origin. *P. trilobus* is spontaneous in the Himalayas and in Ceylon. The mung-bean with its small seeds, is a very ancient crop in India, where it is said to occur spontaneously.

Cicer arietinum L.

The chick-pea is a Mediterranean plant. There are fourteen species from there noted by de Candolle, and only one from Abyssinia. It has long been used in China, and was used in the eastern Mediterranean countries at an early date.

Cajanus indicus Spreng. (*Cytisus cajan* L.)

This may have originated in India, but Africa seems to be the more likely source. It is cultivated across the breadth of this continent, though it is a recent crop in Egypt. In Lango (Uganda) it has an average yield of 600-700 lbs per acre, and is sown with eleusine as a protective crop. It is generally known as the Pigeon-pea.

Vigna Catjang Walp. (*V. sinensis* Endl.).

Is regarded by Pole-Evans (11) as of Central African origin. It is grown over wide areas in Africa and in Asia. It is, for instance, an important crop in parts of East Africa. A number of spontaneous species, closely allied to this type, are known in the Union.

Dolichos Lablab L. and *D. Lubia* Forskal.

Lablab is spontaneous in India and Java, and has had a long history in China. Little is known of the origin of the Lubia; it has long been grown from the eastern Mediterranean to India. Both types occur in Africa as cultivated varieties.

CUCURBITCEÆ.

Cucumis melo L.

While there is a small group of this genus in America, the domesticated form is best represented in Africa, and de Candolle suggests that it was spontaneous without a break, at one period, from Africa to India. It was known to the ancient Egyptians and to the Mediterranean peoples generally.

Citrullus vulgaris Schrad ex E. and Z. (*Cucurbita citrullus* L.).

Is quite certainly of African origin, and spread hence to Egypt, where it is designated in Sanskrit at an early date. Livingstone saw great terrains of wild plants, and the fruit has certainly been used by the primitive Bushmen of the Kalahari and by wild game for great periods.

Citrullus Colocynthis Schrad.

This "bitter apple" is purely of medicinal value, and colocynth is extracted from the dried pulp. It seems to have

been spontaneous both in Africa, where it is sometimes used medicinally, and in parts of Southern Asia.

Cucurbita spp.

Includes numbers of gourds, squashes, etc. *C. Lagenaria* L. is said to be found in Malabar, India and Abyssinia. *C. maxima* Duchesne, the musky pumpkin, is placed by Vavilov as of south Mexican origin. *C. Pepo* L. is probably American, but is said to have appeared early in Africa.

Palmae.

Palm-wine or "toddy" was known to Herodotus in 420 B.C., and has been made by natives of both Old and New Worlds for centuries. Apart from the date palm (*Phoenix dactylifera* L.) of the Mediterranean, the main sources of syrups and sugars in Africa were the indigenous *Raphia vinifera* Beauv., *Elaeis guineensis* Jacq., and *Borassus flabellifer L.* *Elaeis guineensis* yields two oils (in addition to a syrup), that from the edible nut kernel being the finer. *Raphia vinifera* is common in the tidal bayous and creeks of the Guinea Coast. In addition to palm wine it provides fibres for mats and brushes. The *Borassus* is common in all tropical countries.

Narcotics and Stimulants.

Coffea arabica L.

Is spontaneous in the Sudan and more especially in Abyssinia, where it was first cultivated. Shehabeddin Ben, a XVth century writer, is quoted by John Ellis (An Historical Account of Coffee) as saying that coffee is very ancient in Abyssinia. It failed to spread to Europe through the Crusaders, and its first use outside Abyssinia, and perhaps Arabia, seems to have been in Egypt in 1596. Wilson and Felkin (17) speak of the Baganda "and their indispensable coffee berry." Roscoe (18) states that coffee has always been cultivated on the islands of Victoria Nyanza, where the berries are boiled and husked, dried and baked lightly, then chewed.

Coffea liberica Hiern., is a native of West Africa, and has recently been cultivated.

Coffea robusta Linden, a native of the Congo basin, and provides most of the Javanese crop to-day. This is almost certainly the coffee noted by Monteiro (19) in Angola, though he quotes a rumour to the effect that it had been spread by European missionaries.

Nicotiana Tabacum L.

Has been so adequately dealt with by Laufer, Hambly and Linton (20) that little need be said of tobacco here. Tobacco was first known to Portugal in 1560, and appeared at the Cape of Good Hope in 1601, whence it spread to Java. The general quick spread from the Congo mouth must therefore have begun

between those two extreme dates. As in the case of bitter manioc, the spread of the plant must have been accompanied by a process completely foreign to Africa. In Pondoland in 1923, the writer observed the complex process. The seeds were first sown in the neighbourhood of the cattle kraal, and manured. When they were old enough, they were transplanted to a field. At the appropriate time the plants were " budded " to drive the growth to the leaves. On ripening, the leaves were cut and matured in a peculiar manner. They were placed on a sleeping mat in such a way that the leaves did not touch. The leaf on the mat was exposed to the sun, and the mat with the leaves in place were rolled up and put away at night. The process was repeated until the tobacco had been cured. Manuring transplanting, budding and curing are all processes completely foreign to the Bantu. It is possible that part of the complex was copied from European South African methods, but in South Africa the tobacco is cured in a penthouse drying shed and later stored to mature.

Cannabis sativa. L.

This plant and its products are known variously as inDara, bhang, banj, hashish, ganza, etc., is widely used in Arabia, Persia, India and Africa. It seems to have been introduced by the Arabs to Africa where it is generally smoked only. Was known also to the ancient Scythians, and Herodotus describes how they (IV. 75) " take the seed of this hemp, creep under felt coverings, and throw the seed on to red-hot stones . . and the Scythians in delight with this vapour-bath, howl like wolves." Is found wild south of the Caspian, in parts of Siberia about Lake Baikal, and has had a long history in China. Its use and abuse is widespread in Africa, and pipes for the smoking of the plant are known from early Hottentot sources, pointing to a wide and fairly early dissemination of the drug through the continent. Keane (21) gives a short account of the effects of bhang on a whole tribal or national group, the Shilange, since 1870.

Various Plants.

Musaceae.

The bananas and plantains are very widespread, and are often spoken of as of African origin. Actually, the banana is quite clearly a native of south-eastern Asia, but it has spread so successfully that about 300 varieties are to be found in different parts of the world to-day. It was an important fruit in Assyria, 3,000 years ago, and was well known from other early civilisations. Pliny (Hist., Lib. 12, cap. 6) says that the Greeks of Alexander's expedition saw it in India where " the wise men sat beneath its branches." Hence the name *Musa sapientum* L. The Persians associated the banana with the legend of the garden of Eden, hence the synonym *Musa paradisiaca* L. In Uganda Roscoe (18) says there are over two hundred varieties of banana and plantain grown and named by the natives. Thomas and

Scott (12) state that the number of plantain varieties grown in Uganda yield more than a hundred native names. They are used for beer-making, cooking, roasting or for eating raw. In addition there are types of true banana. A plantain garden produces from four to six tons of fruit a year. That the banana has not had a long spread to the southern tropics is suggested by the statement that the King of the Barotse had a single grove of trees dedicated to his own use at the middle of last century. It was only used medicinally.

Sesamum indicum L.

All the ten known species of *Sesamum* are African according to de Candolle, but the domesticated form seems to be widespread, extending from Africa to South Asia, where it is to be found spontaneous in Java. Cultivation in Asia has continued over a great period for oil production. Chinese writers, however, regard the sesame as of recent post-Christian introduction. Pliny speaks of a wild sesame in Egypt, but gives India as the original source of the oil-bearing variety. Its introduction to Egypt was between 1000 and 500 B.C., while it was used in India before that time. It so happens that the American stocks were taken from the Guinea coast to Brazil by the Portuguese.

Hibiscus esculentus L.

The edible *hibiscus*, the unripe pods of which provide a mucilaginous basis for soups, is of Abyssinian origin, but was cultivated in Europe after the crusades, by A.D. 1216. It is found wild in Abyssinia, Kordofan, the Upper Nile and elsewhere in Africa where it is generally known as gombo or okra.

Analysis.

We may express the conclusions yielded by the foregoing notes in the form of an analytical list. The name of the plant is given, the most likely source of the domesticated variety, and the channel by which it apparently reached Africa. To clarify the necessarily short terms used, a few preliminary remarks are essential.

Most of the indigenous African plants are products of the central parts of Africa, intimately related to the summer rainfall belts and to the central perennial rainfall region. In their confinement to that region, the Sahara, in its present form, plays an important part. It is likely that the food-plants credited to Ethiopia are markedly different from other African forms, owing to the selective action of the Abyssinian plateau. As Vavilov has suggested, the folding and uplifting of mountain regions seems to be conducive to the production of new species and varieties. Several are marked as at Afrasian origin, and have their present distribution interrupted by recent conditions in the Sahara. Quite recently, at a time preceding their domestication by man, certain plants had an uninterrupted distribution from south-western Asia to central Africa. This spontaneous distribu-

tion may have been related to the earlier winter rainfall region of North Africa. In such cases it would be essential in seeking the origin, to apply de Candolle's methods and seek the nearest spontaneous varieties, rather than to attempt to apply the methods of Vavilov.

In giving the channel by which these food-plants have reached Africa, I have often employed the word "Migration." The use of the term will be explained more fully in the next portion of this paper. No channel is, of course, given for African plants, unless as in the case of *Oryza*, the domesticated variety is of extra-African origin. The headings Portuguese and Arab have been used for the bearers of many food-plants. Under "Portuguese" are grouped various European nations who were concerned in the slave-trade to the Americas and West Indies, and who almost exclusively affected the western seaboard of Africa. While most of the plants concerned are certainly recorded as having been brought by the Portuguese in the first instance, some or additional varieties were as certainly brought from the New World or from Europe by other nations. This process is still continuing. Under the heading "Arab" are included others, often of the Islamic complex, the Persians who colonised East Africa, the Indians who traded across to that region, the Turks whose main penetration was towards the Niger, and others.

Two other possible carriers of food-plants have not been noted in the analysis. As early Chinese traders touched the East African coast (22) it is possible that they too brought seed from the Far East. This channel is ignored as the regions from whence these Chinese traders came had a completely different group of food-plants from those appearing in Africa, save, again, the anomalous *Oryza*. They came from regions outside the sub-tropical belt of southern Asia, and it seems unlikely that they brought tropical foods to Africa from intermediate ports of call. Much the same may be said of the Phoenician circumnavigation of Africa. The grain they had at their disposal in the Mediterranean was not disseminated in Africa. It is simpler to attribute the spread of the few Mediterranean plants common in Africa to diffusion or migration across the Sahara.

Migration.

The heading, Migration, in the analysis needs some further explanation. Here are grouped the bulk of the plants originating in south-eastern Asia. There are two hypotheses as to their spread to the African mainland; these are possibly alternative, but are more likely to have supplemented one another. The first we may call the Negro channel, the second the Indonesian.

It has long been noted (21, 23, 26 and elsewhere) that the distribution of the elemental Negro race throughout the world (apart from important slave migrations) is simple and somewhat confined. Negro types, either Pygmies or taller stock, either

PLANT	ORIGIN	CHANNEL
Sorghum vulgare	Africa	—
,, ,, var. *saccharatus*	S. Africa	—
,, ,, var. *caffrorum*	Cent. Africa	—
,, ,, var. *subglabrescens*	Africa	—
,, ,, var. *caudatum*	Sudan	—
Panicum maximum	? Africa	—
,, *miliaceum*	? Mediterranean	—
Echinochloa stagnina	Asia	Migration
Pennisetum typhoides	Africa	—
Eleusine coracana	S. Asia	Migration
,, *tocussa*	Abyssinia	—
Oryza sativa	? Asia	Arabs
Zea Mays	America	Portuguese
Dioscorea sativa	S. E. Asia	Migration
,, *Batatas*	S. E. Asia	Migration
Manihot utilissima	S. America	Portuguese
Ipomoea Batatas	C. America	Portuguese
Voandzeia subterranea	Africa	—
Arachis hypogea	Brazil	Portuguese
Vicia Ervillia	Mediterranean	—
,, *Faba*	Mediterranean	—
Lens esculenta	Mediterranean	—
Phaseolus vulgaris	Mexico	Portuguese
,, *lunatus*	Peru	Migration
,, *trilobus*	S. Asia	Migration
,, *Mungo*	S. Asia	Migration
Cicer arietinum	Mediterranean	—
Cajanus indicus	Africa	—
Vigna catjang	C. Africa	—
Dolichos Lablab	S. Asia	Migration
,, *Lubia*	S. Asia	
Cucumis melo	Afrasia	—
Citrullus vulgaris	Africa	—
,, *colocynthus*	Afrasia	—
Cucurbita Lagenaria	Afrasia	—
,, *maxima*	Africa	—
,, *moschata*	Mexico	Portuguese
,, *Pepo*	America	Portuguese
Coffea spp.	Africa	—
Nicotiana tabacum	America	Portuguese
Cannabis sativa	Capsian region	Arabs
Musaceae	S. Asia	Migration
Sesamum indicum	? Africa	—
Raphia vinifera	Africa	—
Elaeis guineensis	Africa	—
Borassus flabellifer	Africa	—

relatively pure or in predominantly Negro mixtures, are spread in a great semi-circle (the Negro Belt) with the centre of its distribution in the general region of India. The south-western arm provides the basis of the population of Africa from the Sahara to the Karoo. The south-eastern branch is scattered in the islands of Oceania, with marked foci in New Guinea, Melanesia and perhaps in Tasmania. In Asia no decidedly Negro types are found north of latitude 35°N., where the Himalayas seem to have provided an insuperable barrier to any movement northward. The problem is admirably expressed by Sir Arthur Keith and M. Krogman (23, p. 320): "The enigma of modern Anthropology is the Black Belt of mankind. It commences in Africa, and peters out amongst the natives of the Melanesian Islands of the Pacific. At each extremity of the belt, in Africa as in Melanesia, we find peoples with black skins, wooly hair, more or less beardless, prognathous and long-headed. We cannot suppose these Negro peoples, although widely separated, have been evolved independently of each other."

If we regard the central point of the Negro Belt as approximating to the original home of the Negro, we may accept the present distribution of the Negro as the product of major late prehistoric migrations from the general region of the Hindostan peninsula. Other evidence has been adequately reviewed by Keane (21), and need not be repeated here save to reiterate that we seem to be dealing with a fundamental and specific racial type, recognisable as a major element in the present populations along the whole Negro Belt, and emanating from one original stock. The distribution along the original route has been cut and divided by innumerable later migrations and crossings of other stocks, but the fundamental Negro element has not been concealed.

There is evidence to show that a long prehistoric period existed in all parts of Africa before the arrival of the true Negro. Seemingly only one prehistorical skull in Africa shows marked Negro characteristics, a skull discovered in the ancient clay-bed of Lake Moeris in the Fayum. Dating is somewhat uncertain, but the earliest ascribable date is 6000 B.C., and the skull is certainly of Neolithic or later date, and therefore belongs to a period later than the invention of plant-cultivation. In southern Africa similar suggestive evidence exists. For instance on the Limpopo, Dr. Galloway (11, Galloway, in *op. cit.*) has shown that the early types at that site were not true Negroes, though the dating of Mapungubwe is astonishingly recent. Seligman (24) points out that a proto-dynastic slate palette from Egypt, datable at 3200 B.C., yields our earliest illustration of a type identified as Negro or Negroid, in Africa. The Negro does not appear historically in Egypt until the great period of Egyptian expansion in about 1500 B.C. Instances might be multiplied, but all the evidence goes to show that nowhere in Africa is the true Negro an ancient race predating the invention of simple hoe-culture.

It is possible, and indeed highly probable, that the sub-Negro Pygmies, hunting stock without agriculture, are remnants of an earlier spread, showing much the same distribution as the full Negro.

The climatic history of the Mediterranean and Sahara preceding and during the Neolithic period, shows that the whole Sahara was more moist that at present (9), and the climatic changes encountered *en route* from Asia were never extreme, ranging from subtropical to Mediterranean conditions, then back to subtropical. These plants need never have encountered extreme arid conditions in their spread to Africa. Perhaps certain plants (e.g. *Oryza sativa*) could not have survived this land route, and we do know that the cultivated stocks of this plant are late appearances, in part historically attributable to Arab and European peoples.

It is essential to bear in mind that this hypothesis rests upon existing anthropological evidence of a fundamental unity underlying the Oceanic and African Negro stocks. Work on the basic Negro type, with an attempt to isolate Boskopoid and other African physical elements is being undertaken at the University of the Witwatersrand. Much depends upon the applicability of such an analysis to the Oceanic Negro, once other Oceanic strains and characteristics have been isolated and eliminated.

It remains only to point out that the various cultivated Dioscoreae, and perhaps certain other food-plants, had a distribution much the same as that of the Negro, with a wider spread extending from the Negro Belt. There is room therefore for the presumption that the Negro himself developed this particular root-crop, and perhaps we owe to him the domestication of some others of the South Asiatic food-plants listed above.

The alternative route from south-eastern Asia to Africa is by sea. We know that Indonesians from the southern Malay Peninsula and from southern Sumatra colonised Madagascar from the second to the tenth centuries of our era, in two distinct migrations. The evidence in the physical make-up and obvious in linguistic and cultural elements is too marked to need description here. The whole position has been summarised in a comprehensive manner elsewhere (25). These relatively late migrants traded with Sofala and other points on the East Coast of Africa for slaves and iron, and have left their mark on certain elements of material culture on the mainland.

Many years ago the German ethnologist Ankermann (working in conjunction with Grabner, who undertook the Oceanic field) drew attention to certain cultural elements in West Africa, showing a strong superficial resemblance to elements found in Indonesia. From Madagascar to West Africa the route along the tropical Zambesi valley provides an almost ideal route for the penetration of elements of culture, including plant types (26)

Whether the diffusion of individual culture elements has been from the mainland to Madagascar, or in the opposite direction, we do not yet know. Each element would have to be studied individually in its relation to Indonesia, Madagascar and West Africa, but the possibility of like ecological conditions producing superficially similar material culture would have to be eliminated.

It is sufficient here to suggest that some at least of the food-plants credited above to "Migration" may have been brough to Africa by the direct route from Indonesia, and diffused from the East Coast, much as tobacco and manioc spread from the West Coast. This would imply the somewhat late appearance of plant types which have built themselves so fundamentally into African culture that they have every suggestion of being early.

Conclusions.

1. During the actual Negro migration, and before reaching Africa, these folk had at their disposal the following plants: *Echinochloa stagnina*, *Eleusine coracana*, *Dioscoreae*, *Phaseolus trilobus*, *P. Mungo*, *Dolichos Lubia*, and *D. Lablab*, together with the *Musaceae*. The Indonesian origin and migration by way of Madagascar and the Zambesi of some of these plants must be considered as an important probability.

2. In their passage across the Eastern Mediterranean countries the migrating Negroes were in a position to add *Ers spp.* and *Cicer arietinum*, but diffusion or migration across the Sahara must not be ignored.

3. Once within the continent they developed or cultivated certain indigenous plants with food value, and have given these to the world; *Sorghum vulgare*, var. *saccharatus*, *S. vulgare*, var. *caffrorum* and *var. subglabrescens*. *Pennisetum typhoides*, *Voandzeia subterranea*, *Vigna Catjang*, *Citrullus vulgaris*, some *Cucurbitae*, *Raphia vinifera*, *Borassus flabellifer*, *Elaeis guineensis*, *Sesamum indicum*, *Hibiscus esculentus*.

4. From Ethiopia, either from early Hamito-Semitic cultivators of the plants, or from development by the Negroes themselves in that region, they obtained *Andropogon sorghum*, *Eleusine tocussa*, and a knowledge of *Coffea arabica*.

5. The following have a distribution in both Africa and Asia, and we can presume nothing in regard to their origin: *Panicum miliaceum*, *Cucumis melo*, *Citrullus colocynthus*.

6. In recent times the following species have been added by Arab and other colonisers from the Indian Ocean: *Oryza sativa* and *Cannabis sativa*. Similarly, colonisers from the Atlantic side, mainly (like the Arabs) slave-raiders, have given Africa the following plants: *Zea Mays*, *Manihot esculenta*, *Ipomoea batatas*, *Arachis hypogea*, *Phaseolus vulgaris*, and *P. lunatus*, *Cucurbita moschata*, and *C. Pepo*, *Nicotiana tabacum*.

Once the plants of the new environment had been cultivated, the Negro had at his disposal some twenty-five types of cultivable or usable plants, a figure far in excess of that suggested by Sir Harry Johnston (10). We are quite certainly indebted to the Negro for the cultivation of a number of foodstuffs indigenous to Africa, and perhaps too for the original importation and acclimatisation of certain southern Asiatic plants. At the same time, it is interesting to realise that the most important food-plants employed by the Negro to-day are in the main of American origin, brought in recompense for the early raping of Africa.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVI, pp. 464-467, December, 1939.*

THE ORIENTAL ANCESTRY OF THE AULAYA-'NYUNGWE

BY

J. BLAKE THOMPSON,

Southern Rhodesia.

Read 4 July, 1939.

In the course of an enquiry into the physical characters, customs and beliefs of various tribes in the Zambesi watershed, I have been fortunate in securing the assistance of Lino, the son of a chief near Tete and a member of the Aulaya-'Nyungwe (Achikunda) royal family. Apart from him, I have asked several hundred members of the tribal groups concerned, namely 'Nyungwe, Asena and Atonga, about various points. The data they supplied, though much less detailed, have elaborated his statements.

The Rhodesian branches of the 'Nyungwe are known as Mahungwe and Manyombe (now Mkorekore, with whom they are mixed). Their boundaries seem to have been the Pungwe (Pa-Hungwe) River, Makoni's country, Urungwe (Mrewa district) and across to Urungwe (Miami district) in the west. There is also a branch in Bulilima-Mangwe and the Bamangwato of Bechuanaland are closely related. Their greeting to the chief is identical with that given to the Mambo of the 'Nyungwe, i.e., "*Pagati.*" The group in question inhabit the Dambo district of Tete province on the Zambesi in Portuguese East Africa.

These natives have a great fund of sea legends and a fixed idea that these tribes had a common origin but that, even before their legendary history opened, the ancestral group had split up, some going far east and others west. At a later period the eastern stock returned by sea and met the descendants of the western stock. They claim to have arrived in Africa before the " black " races, and before the pre-Moslem Arabs but along with the Indians (Mabunda, Mabundu, Mabuda) who were their friends and lived nearer to Africa than they themselves originally did. They claim too that slaves were brought to Africa by their ancestors, and that others were taken away to be sold in the east and that this did not cease until the Arabs and eventually the Europeans interfered with the ancient trade routes. The Atonga, they believe, are of two stocks: one which came eastward from the north-west and called themselves " the free people, who judge and are not judged;" the other were easteners, who claimed descent from a conquered people that came hither via Madagascar.

The modern descendants of these people are very class conscious, having very exact ideas about tribal differences, especially those who are members of present or ancient ruling families. But the tribes to-day are a very mixed group betraying a high degree of oriental admixture. Their skin colour varies from a freckled fair skin to a dark chocolate brown. Generally the body is golden brown, the cheeks reddish and the palms of the hands yellowish; about 5 per cent. show the "Mongolian spot" in infancy. Their own concept of their physical type is that of an elongate face without prognathism, but with high and sometimes prominent cheek-bones, small and round but not receding chin and a lower jaw with pronounced angles. The ears are small, wider than long, inclined to a point on top, set close to the head and only slightly lobulated; the eyes are small, set widely apart, inclined upward at the outer end (more that 5 per cent. have an epicanthic fold), the iris is brown and occasionally greyish and the conjunctiva brownish. The nose is long, the bridge low, the nostrils wide; seen full-face, it is as broad as it is long. The mouth is wide, lips thin and upper lip long. The head is broad, high, square and large, with flat sides and flat occiput, the forehead may have slight eyebrow ridges, but is high, square and straight. Their hair is coarse, and legend says it was straight and long; it is ebony black in colour and never reddish or grey. The beard and moustache are scanty but long; hairlets are plentiful on body and limbs and there is a medium growth over the pubes. Temperamentally, these people are clever, placid, persistent organisers, defensive fighters and proud; they are thus extremely sensitive to good or bad treatment.

Their dominant totem is "Marunga" (salt) or "Runga" (dove); their sacred tree is the date palm; their tribal dance is the dove dance; their tribal music that of the pan-pipe (of which they have nineteen varieties, the sets containing one to six and some say even eight pipes, the different sets varying also in length). They taboo the eating of doves and fish and avoid one or another form of salt. They were smiths, artisans, traders and slaves by occupation. Their clothing consisted of white cotton dresses with short sleeves and a red cotton mantle over their backs, tied with a knot about their necks and further secured with a red waist sash. The men wore a cod-piece made of a goat's scrotal skin and ornamented with long cylindrical beads hanging pendent therefrom. Their feet were shod with wooden sandals secured by leather straps; their ornaments included beaded anklets, armlets and leg bands, beaded fringes on their robes and sleeves and beaded plaques on the fringes. As headgear they used wide-brimmed hats of woven palm fibre, with a narrow-waisted crown and a bulge on top, which was dented in in the centre; there a button was fixed and into it an eagle's feather was stuck. The hats carried a band of red, black and white beads and a pom-pom decorated with beads adorned the front and the sides above each ear.

I have gathered much further information, which need not be given here, about their dwellings, which were frequently made of stone walls (as well as wooden poles and thatch) and also about their burial customs. They used the chevron pattern and erected monoliths; they quarried with fire and water and dressed their stone walls. Iron, copper, gold, silver and other malleable metals were worked. They executed writing by means of paintings on rocks which once were readable, but are now imperfectly understood. They still draw in the sand to illustrate their meanings when talking.

THE STORY OF THE COMING OF THE AULAYA.

Their legends, as handed down to their descendants, the 'Nyungwe, and as told by Lino Benkudo Piloto, living descendant of Ming Yung (usually "bantuised" to Munyu), their leader who settled at "Nshawa" on the Sabi (Shawa) River.

The Aulaya lived in the kingdom of Milanje* three months journey by ship from Madagascar (called by Lino under its old name Malaka). Every year the Aulaya used to come from Milanje to Africa bringing oxen, metal work and other articles to trade with the natives (not the Bantu who had not reached Southern Africa then). They returned with ivory, gold and slaves. At Malaka they mixed with the Cerne people, who used outrigger canoes. Some of these people came to Africa with some Adema (a Pygmy or Bushman tribe) and are now known as the Achiwambo, to whom his people think the Zulus are akin in looks. Another tribe which the Aulaya met in Malaka were the Matsimalaka, some of whom came over to Africa in small sailing canoes. These people are the Sena or Apodzo tribes.

In the Empire of Milanje there are high mountains which smoke and throw up rocks; these mountains are above the flight of the eagle. It was there that the Aulaya lived at Nkwazi (sometimes pronounced Nkwanzi, sometimes Nya Nkwang tsi); but the mountain shook and threw rocks down on the people so that they fled and later came to the sea shore among the bamboos and palm trees and rice, also the ground nut. Here they learned to make ships and to become seamen. They made their ships large enough to carry 40 to 60 people, besides the slaves at the oars, cattle (humped), trade goods and food for the journey to Africa. These ships were made of bamboo tied together and caulked with hippo dung mixed with beeswax and some black material. This was trodden into the seams and a store kept on board in case the ship leaked at sea. Palm tree trunks made the masts and the sails were either of bamboo or palm leaf matting. The ships were decked, with houses on the deck. When the ship was becalmed, large oars were put out

* When I spoke, after this statement, of Edrisi's "Empire of Mihradj," Lino said that that is how Arabs say words like Milanje. He did not know that Edrisi was an Arab.

at each side and the ship rowed by slaves. The chief or captain lived in front of the mast and he had an instrument like a tail, which showed him the way across the sea. Their great captain was called Ming Yung (Munyu). These people met and were friendly with Indians (Mabundu), who wore high hats with ear flaps and long robes and many ornaments. These people also traded with Africa, sometimes going long journeys on camels. They built altars and offered burnt offerings of goats' flesh. They also burned their dead within circular walls of stone. The Mabudu knew the Aulaya in the East before they came to Africa.

When an Aulaya chief died, a wall was built with bands of patterned stone work in it to prevent the snake (Python), which carried on the spirit of the chief's family. A monolith was erected on the wall so that in a wall with many monoliths, each monolith represents the spirit of a chief. Very great chiefs had very large monoliths.

From Malaka (Madagascar) it took two months to reach Nshawa, the Aulaya port above the delta of the Sabi River. (This port was left dry owing to the river changing its course and is now further inland). There were other ports of these people to the South, even farther South than Delagoa Bay. One port was known as Ku Drabuja. From Nshawa the ships came North up the coast to one of the mouths of the Zambesi (which they know as Duanya) halting above the delta near a mountain (which they call Malangwe) and then up to 'Nyungwe (Tete). The total journey took three months from Malaka; the distance was short but the wind and sea made the voyage from Madagascar dangerous and slow.

When the Aulaya first came to Tete there were no fixed inhabitants, but only some people who appeared from time to time. These were fair-skinned (not Bantu). They spoke with a click like monkeys, but were taller than the Pygmies and they herded cattle. These people the Aulaya called Chiponda; a branch of them mixed with the Bantu and live in Northern Rhodesia.

The first Bantu to meet the Aulaya used to call them *Wanu wa Mvura Chena* (People of the White Water) because they came across the salt sea. Later the Atonga called them Asungu because they (the Aulaya) were like the ground nut, *'Nzungu*, which they brought. One branch of the Aulaya was known as Mabaka, another as Chin Sing (now Chinsinga). The principal branch to-day is the 'Nyungwe.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVI, pp. 468-473, December, 1939.*

THE PROFILE OF THE FACIAL SKELETON IN NEGRO, BUSH AND EUROPEAN SKULLS

BY

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With 1 Text Figure and 1 Table.

Read 4 July, 1939.

This investigation, which was undertaken as part of a more extensive study of the facial skeleton in South African native types, has as its object, the definition of the profile of the facial skeleton in terms of fixed anatomical points. For this purpose measurements have been made on three series of fully adult skulls. The first series is made up of fifty Zulu and fifty-two Basuto skulls; I have felt justified in treating these together as representing the South African Bantu-speaking Negro peoples, since Dr. A. Galloway, in an investigation now in progress, has determined that no significant difference can be found between these groups in metrical or non-metrical features. The second series consists of thirty-five European skulls, and the third of fifty-three Bush skulls. Nineteen of this last group belong to the collection of the Port Elizabeth museum, while all the other specimens form part of the collections of the Department of Anatomy, University of the Witwatersrand.

The method employed in this study was suggested to me by Dr. Milo Hellman. By means of the head spanner devised by Wingate Todd (Todd and Keunzel, 1924), radial measurements were made from the centre of the auditory meatus (auricular point) to four points on the facial profile, viz., nasion, rhinion, subnasion and prosthion. Calliper measurements were also made of the distances between nasion and the other three points. From these measurements, the following indices were calculated:

$$\frac{\text{nasion-rhinion x 100}}{\text{auriculo-nasion}} \quad \text{(N—R index)}$$

$$\frac{\text{nasion-subnasion x 100}}{\text{auriculo-nasion}} \quad \text{(N—S index)}$$

$$\frac{\text{nasion-prosthion x 100}}{\text{auriculo-nasion}} \quad \text{(N—P index)}$$

$$\frac{\text{auriculo-rhinion x 100}}{\text{auriculo-nasion}} \quad \text{(A—R index)}$$

$$\frac{\text{auriculo-subnasion x 100}}{\text{auriculo-nasion}} \quad \text{(A—S index)}$$

$$\frac{\text{auriculo-prosthion x 100}}{\text{auriculo-nasion}} \quad \text{(A—P index)}$$

Thus, the measurements have been referred to the auriculo-nasion distance as a standard. In addition, the index $\frac{\text{auriculo-prosthion x 100}}{\text{auriculo-subnasion}}$ has been calculated as a measure of subnasal prognathism.

In order to simplify the investigation, it was decided to disregard, for the present, the absolute measurements which differ appreciably in the various groups, and to make the comparisons on the basis of the indices. The range, mean, standard deviation and number of observations of each index for the three series are set out in Table I. It will be noted that the number of observations differs slightly among the different indices, since all of the measurements could not be taken on each skull. Besides comparing the means for the three series statistically, a graphical comparison has been made by plotting the relative positions of the five anatomical points, as determined by the means of the indices for each group, in relation to the Frankfort horizontal plane. The mean position of this plane in relation to rhinion and subnasion was determined from dioptographic tracings of a representative series of skulls of each type. These showed that the Frankfort plane cut the line rhinion-subnasion 35 per cent. of that distance from rhinion in the European, 25 per cent. in Zulu-Basuto group, and 22 per cent. in the Bush series.

From these findings, Fig. 1 has been prepared. In this figure, the relative positions of the anatomical points for the three series were plotted, the auriculo-nasion distance being taken as 100. The three sets of points have been superimposed on the Frankfort plane so that the auricular points coincide, and a schematic profile traced through the four facial points of each type.

This figure shows that when the profiles are superimposed in this manner, there is a considerable difference in the vertical height of nasion above the Frankfort plane. The nasion of the European falls very close to that of the Zulu-Basuto group, the latter being slightly lower; that of the Bush is, however, considerably lower than either. Further, since the auriculo-nasion distance has been made equal for the three types, it follows that nasion is situated relatively farthest from a vertical line through the auricular point in the Bush, and nearest to it in the European.

Table 1 shows the mean of the auriculo-rhinion index to be greatest in the European (107·89) and least in the Bush (100·21),

TABLE I.

INDEX	ZULU-BASUTO	BUSH	EUROPEAN
$\frac{\text{A-Rhinion} \times 100}{\text{A-Nasion}}$			
No. of Observations	102	48	35
Range	97·7—112·5	94·6—105·7	99·0—113·9
Mean	101·24 ± 0·53	100·21 ± 0·78	107·89 ± 1·12
σ	2·7	2·7	3·3
$\frac{\text{A-Subnasion} \times 100}{\text{A-Nasion}}$			
No. of Observations	102	51	35
Range	94·9—109·6	93·8—107·2	94·0—109·3
Mean	101·92 ± 0·67	100·16 ± 0·83	100·78 ± 1·29
σ	3·4	2·96	3·87
$\frac{\text{A-Prosthion} \times 100}{\text{A-Nasion}}$			
No. of Observations	102	50	35
Range	98·0—122·9	93·9—119·3	91·1—116·5
Mean	111·82 ± 0·87	108·0 ± 1·40	103·66 ± 1·75
σ	4·4	4·96	5·18
$\frac{\text{A-Prosthion} \times 100}{\text{A-Subnasion}}$			
No. of Observations	102	51	35
Range	101·0—115·9	100·0—113·8	95·8—110·9
Mean	109·69 ± 0·54	107·76 ± 0·87	103·26 ± 1·15
σ	2·74	3·1	3·4
$\frac{\text{N-Rhinion} \times 100}{\text{A-Nasion}}$			
No. of Observations	102	50	35
Range	11·8—34·8	9·3—28·9	11·3—33·7
Mean	23·78 ± 0·76	19·84 ± 1 14	22·23 ± 1·82
σ	3·86	4·04	5·39
$\frac{\text{N-Subnasion} \times 100}{\text{A-Nasion}}$			
No. of Observations	102	50	33
Range	43·8—66·3	45·2—57·8	51·0—65·1
Mean	54·8 ± 0·7	50·36 ± 0·85	56·97 ± 1·18
σ	3·53	2·99	3·38
$\frac{\text{N-Prosthion} \times 100}{\text{A-Nasion}}$			
No. of Observations	102	50	35
Range	63·4—90·4	57·3—76·8	64·5—83·6
Mean	76·27 ± 1·15	67·88 ± 1·30	75.2 ± 1·59
σ	5·8	4·6	4·7

the Zulu-Basuto group lying almost midway between them. Statistically, the difference in the means is very significant. Thus, as is shown in Fig. 1, rhinion in the European lies much farther in front of a vertical line through nasion than in the Bush, that of the Zulu-Basuto group taking up an intermediate position. The N-R index shows that the relative length of the nasal bones is greatest in the Zulu-Basuto group and least in the Bush (Table I), the difference between these series being significant. This index takes up an intermediate position in the European, not being significantly different from the Zulu-Basuto series, and only doubtfully so from the Bush group.

It has already been stated that 35 per cent. of the rhinion-subnasion line lies above the Frankfort plane in the European as against 25 per cent in the Zulu-Basuto group and 22 per cent. in the Bush. A considerably larger proportion of the nasal aperture is therefore situated between the orbits in the European than in the African native types. Fig 1 shows that as a result of this, the vertical height of rhinion above the Frankfort plane is greatest in the European and least in the Bush series.

As Table 1 shows, the radial distance of subnasion from the auricular point (A-S index) varies but little in the three groups. While the difference between the values for the Bush and the Zulu-Basuto groups is statistically significant, the intermediate value given by the European series is not significantly different from either of these. The close approximation of the auriculo-subnasion to the auriculo-nasion measurement is also noteworthy. The nasion-subnasion line (N-S index) is greatest in the European and least in the Bush series, with the Zulu-Basuto group approaching more closely to the former; the differences are significant throughout. However, when the three profiles are orientated on the Frankfort plane, the position of subnasion is found to be almost constant. Thus the difference in the nasion-subnasion distance is to be found entirely in the interorbital region. It appears then that the inferior margin of the nasal aperture as expressed by subnasion has an almost constant relationship both to the auricular point and to the inferior orbital margin. If this is confirmed by further studies, it must be of the greatest value in craniological investigations.

There is a conspicuous difference between the three groups in the radial distance from the auricular point to prosthion (A-P index). This is greatest in the Zulu-Basuto group (Table I) and least in the European; the Bush series stands mid-way between the two and is significantly different from both. The nasion-prosthion distance (N-P index) on the other hand, is practically the same in the Zulu-Basuto and European groups, but very much less in the Bush series. When the profiles are superimposed on the Frankfort plane (Fig. 1), it is found that the vertical distance of prosthion from that plane varies but little, being greatest in the Zulu-Basuto and least in the Bush group. In relation to the auricular vertical diameter, however, there is

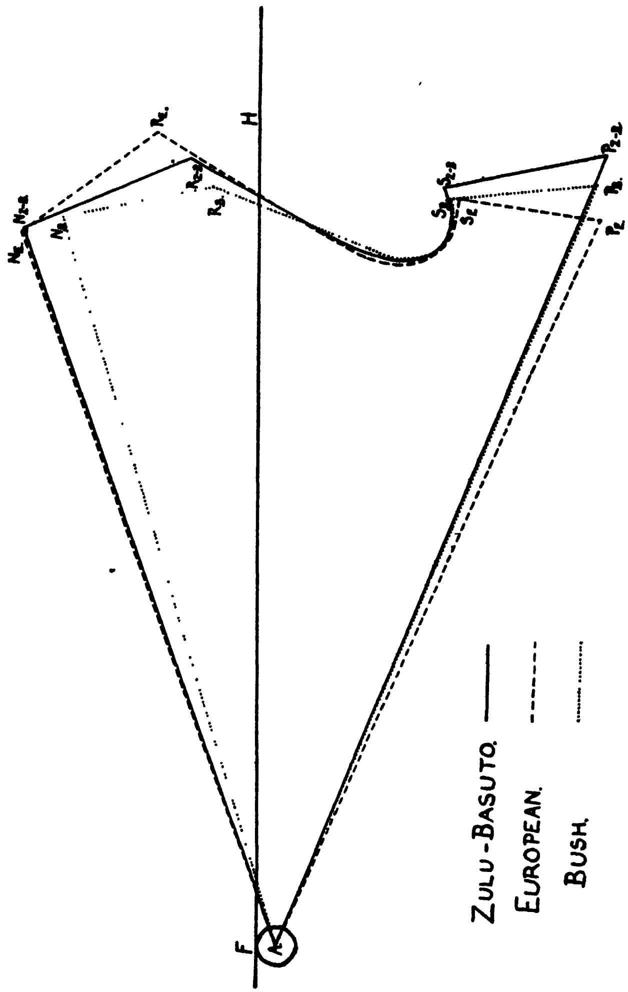

Fig. 1.—Schematic profiles of the European (E), Zulu-Basuto (Z-B) and Bush (B) types, constructed from the mean indices listed in Table I.

a marked difference, prosthion being projected forwards in the Zulu-Basuto group and to a less extent in the Bush series, whereas in the European it is retracted. Indeed, in the European this point lies just behind a vertical through subnasion.

This difference is reflected by the $\frac{\text{A-P}}{\text{A-S}}$ index (Table I), which is less in the European than in the Zulu-Basuto group, the Bush index being nearer the latter but still significantly different from it. These values are, however, also influenced by the differences

in the vertical level of prosthion. Since the position of subnasion is nearly constant, the relatively anterior and inferior position of prosthion in the Zulu-Basuto group implies, as shown by Fig. 1, a greater elongation of the subnasal region in this group, as compared with the Bush in which prosthion is higher and more retracted. The European with its low, but retracted prosthion, occupies an intermediate position.

Thus, in the European series, nasion is high and retracted, the nasal bones are relatively long and project very far in front of nasion. The nasal aperture is high, about a third of its height lying above the Frankfort plane. Subnasion is low and retracted, and the subnasal region is short and retracted so that prosthion falls behind a vertical through subnasion and only just in front of the vertical through nasion.

The profile of the Zulu-Basuto group has nasion in a position almost corresponding to that of the European, being slightly lower and anterior. The nasal bones are relatively longer than in the European, but do not project as far forwards. In the Zulu-Basuto group only one quarter of the nasal aperture lies above the inferior orbital margin and subnasion is highest and most anteriorly projected. The subnasal region of the Zulu-Basuto series is long and projects markedly in front of the inferior margin of the nasal aperture.

The Bush series has nasion placed low and well forward. The nasal bones are short and not set at a very great angle to the vertical. The nasal aperture is short and less than a quarter of it is interorbital. Subnasion is not far forward and the subnasal region is just longer than that of the European. Prosthion is set between that of the Zulu-Basuto and European groups, lying well in front of a vertical through subnasion and on the same vertical plane as rhinion.

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South African Journal of Science, *Vol. XXXVI, pp. 474-476, December, 1939.*

A CHINESE CHARACTER AS A WALL MOTIVE IN RHODESIA

BY

Raymond A. Dart.

With 1 Text Figure.

Read 4 July, 1939.

In view of Mr. Blake Thompson's communication concerning the oriental origin of the Aulaya, I have decided to place on record my information relative to the above matter. On his return from excavation work at Penhalonga in Southern Rhodesia several years ago, Mr. A. York Mason informed me about a curious story he had heard from Father Shropshire of St. Augustine's Mission. This story was subsequently corroborated by Mrs. C. Martin, who wrote to Father Shropshire and received the following reply in answer to her request for a statement upon the subject:

" A Chinaman, who had been travelling over the world studying educational systems, was sent by the Educational Department of Southern Rhodesia to St. Augustine's Mission, Penhalonga, and I took him with me on trek to see some of the village schools. When we entered the first school (built of trees, mud and thatch) at Ndarangwa in the Hondi Gorge, he noticed, immediately, a geometrical design on the wall about which he became very excited and demanded to know its origin. I told him I did not know its origin, but that it was a design commonly used on walls and on the clay pots which the natives make. This did not content him, so I called the native village teacher, who also could not give any information as to the origin of the design, which, I could see, disappointed the Chinaman very much. I then asked him why he was so excited and anxious about the matter, and he replied in broken English, ' Why, that's my name.' "

The incident created so strong an impression upon the Chinese scholar that, when inscribing his name in the visitors' book at the Mission, he signed his name in both English and Chinese. When the Mission authorities learnt of our interest in the incident, they kindly cut the whole signature out of their book, so that it might be sent to Father Shropshire for identification of the symbol. He reported that " as far as he can remember " the character is the one on the left-hand side at the top.

The original signature has been kept on file at the Medical School at Johannesburg since 1935, but as it was in pencil, and so rather difficult to reproduce, I made application to Mr. Sung, the Chinese Consul here, to have it reproduced in his office. The copyist, in so doing, has altered the disposition of the symbols so that they are read from above downwards and from left to right in the proper Chinese fashion (instead of horizontally from left to right as they had been placed in the visitors' book). This re-arrangement in no way affects the position of the top left hand symbol referred to by Father Shropshire. The copied address and signature are reproduced here (Fig. 1).

田中修

山西稷山

Signature (left column) and address (right column) of:

C. H. Tien,
Tsishan,
Shansi,
China.

Copied by favour of the Chinese Consul, Johannesburg, 1939.

Fig. 1.

An Arab ambassador took a Negro slave to the Chinese court in the Sung Dynasty (A.D. 976). The Chinese-African trade was so great in Alberuni's time (circa A.D. 1030) as to be affecting the size of the ports in India (e.g., Somanath in the Gujerat Peninsula). It was re-established during the succeeding Mongolian (1280-1360) and Ming (1358-1644) dynasties as far south as Madagascar, thus extending over six centuries. The oriental commerce was responsible for spreading the negro race through the East Indies and into Melanesia in the same way as the occidental slave trade dispersed the negro race through the West Indies and America. It made the Bantu language,

Swahili, the *lingua franca* of the Indian Ocean. We know from Marco Polo's records that this Chinese trade extended as far south as Madagascar and from the Chau-ju-k'ua that its objectives were ivory, rhinoceros horn, gold, ambergris, tortoise-shell, animal skins, amber, sandalwood and particularly slaves (vide Ingram's *Zanzibar, its History and its People*, 1931).

Fourteen years ago I reported (*Nature*, 21st March, 1925) on the Chinese hats found depicted in Bushman drawings by Brother Otto as far south as the Kei River near East London. Years later a dug-out canoe made of Malayan wood was dredged out of Algoa Bay at Port Elizabeth; it is preserved in the local museum (Vide *Nature*, 1927, 21st May, 13th August and 29th October). Hornell (J.R.A.I. 1934, pp. 305-352) has since discussed in great detail the nature of Indonesian influence on East African culture and pointed out that the Indonesian type of outrigger canoe is common along the East African coast from Mozambique to the Comoro Islands.

Mongolian features are found among the Cape Bushmen of the extreme southern end of the Kalahari Desert (vide Dart, *Bantu Studies*, 1937). Hence although distant oriental contacts with Africa extended down to and may probably have been most extensive during the Ming dynasty they must date back to a time period long prior to the arrival of the Bantu in Rhodesia or the Union of South Africa.*

In the paper referred to above, I pointed out the numerous non-indigenous but oriental cultivated plants found in Rhodesia and the whole question of non-indigenous plants has been minutely examined by Mr. A. J. H. Goodwin in the present number of this journal. The importance of Mr. C. H. Tien's discovery of the symbol of his own name on a decorative motive on a native school wall lies in the fact that taken alone it might be regarded as an extraordinary and inexplicable coincidence, but taken in conjunction with the steadily accumulating evidence —which has been further expanded by Professor Kirby's researches into the oriental origin of African musical instruments and intensified by Frobenius's discovery of oriental influences in African smelting furnaces and stone buildings—this name symbol links Rhodesia directly with China, in which country alone that character could have been evolved. For about seven hundred years (i.e., A.D. 976-1644) the Chinese knew about and were in contact with Africa; a considerable part of the ethnographical problem in Africa is to determine the relative contributions of China and the intermediate territories fringing the Indian Ocean to the cultures of the Bushman, Hottentot and Bantu peoples as we find them to-day.

*** Since this paper was read Mrs. C. E. Fripp has published an article (*Nada*, No. 17, 1940), setting forth various Chinese historical references to their trade with Africa.**

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVI, pp. 477-488, December, 1939.*

MUSICAL INSTRUMENTS OF THE CAPE MALAYS

BY

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With 2 Text Figures.

Read 4 July, 1939.

INTRODUCTION.

Towards the end of December, 1938, I had an opportunity of investigating certain musical instruments known to have been in use among the Malays of Cape Town for many years, but about which little precise information was available. This paper represents the fruits of my investigation.

The instruments which I observed in regular use were

1. *ghomma*, a kind of drum, and
2. *guitar*, the typical European instrument.

Of these the first appeared to be a relic of some early type of drum, indigenous or imported, while the latter effectively concealed the fact that it was a relatively modern substitute for a simpler stringed instrument belonging to one or other of the races from which the slaves of the Cape were recruited.

It is the purpose of this paper to attempt to marshal the principal relevant facts about these instruments and their possible predecessors, and to try to identify them with the peoples to whom their introduction into South Africa may have been due.

THE INSTRUMENTS.

Both *ghomma* and *guitar* were used by the Malays as an accompaniment to songs, though of different classes, these being

(a) *ghommaliedjies*, or marching-songs, which were all accompanied by the *ghomma*, and

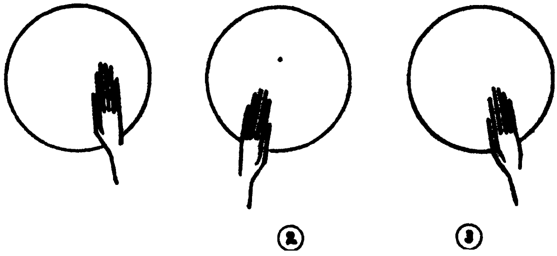
(b) *lyrical songs*, which were accompanied by the *guitar* (1).

1. GHOMMA.

The *ghomma* used in the songs of the first class was made from a small cask with a skin nailed over one of the two open ends, the cask itself being decorated with coloured paint.

The instrument was held by the player under the left arm and was struck alternately by the right and left palms. The

rhythms executed by the performers were all relatively simple though made more interesting by reason of the varied tone-colour obtained by striking the drum head at different points. There appeared to be three points at which the *ghomma* was struck, and these may be indicated diagrammatically thus:—

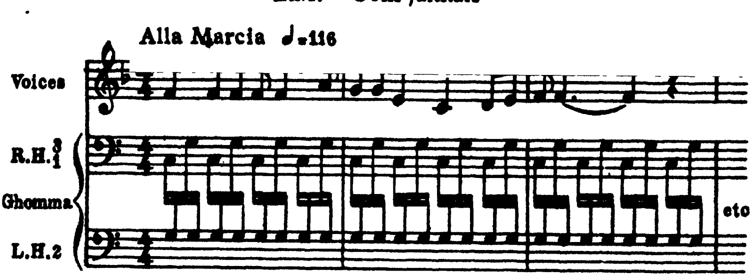


1. Right palm striking drum head.
2. Left palm striking edge of drum head.
3. Right palm striking edge of drum head.

It will be seen that while there are two positions in which the right palm strikes the head, there is only one for the left. The position in which the drum is held may account for this.

A musical illustration will show clearly the actual use that is made of the instrument.

Ex. I. "Oom Jakkals"



In this example all the drummers execute the same rhythmic scheme, which I have set down in such a way as to indicate the various types of beat used. The note C on the middle stave corresponds to the first position on the diagram, the note G on the same stave corresponds to the third position, and the note C on the lowest stave to the second.

It should also be noted that in this example, and in others that I heard, the *ghomma* players joined in after the singers had performed one complete measure; that is, after the time had been definitely established.

In one *ghommaliedjie* the rhythmic scheme used in the song quoted above was used by the principal drummer, but a second

player executed a simplified version of it, consisting merely of quaver alternations of the first position of the right hand and the usual position of the left.

The earliest South African reference that I can discover to the use of such a drum by slaves of the Colony occurs in a rare work descriptive of life at the Cape in 1820. Describing the "Sunday-dance" of the slaves, the anonymous author says: "The irregular beating of a log of wood, hollowed and covered at one end with an undressed sheepskin in imitation of a drum, adds to the noise" (2).

What is the origin of this single-headed cylindrical drum? The answer to this question is difficult to find because of the extraordinary mingling of racial types that at the Cape went to the making of those peoples who are nowadays generally called Malays in Cape Town; a mingling which is not only paralleled, but even exceeded, by the still more extraordinary mingling of racial types that went to the making of their ancestors in the Eastern Archipelago.

Liebbrandt, dealing with a period of just over fifty years, refers to slaves imported into Cape Town from Coromandel, Bengal, Malabar, Ceylon, Java, Bali, Macassar, New Guinea, Cochin, China, Tranquebar, Manado and Madagascar (3). By which of these assorted peoples was the *ghomma* or its prototype imported into South Africa?

Well, the single-headed cylindrical drum is found among the many drums of India, *but only in the hands of Mohammedans.* It is there called *dolu*, or *dhol* (4). It is sometimes double-headed, and the resonator is made of copper. It is played either with the hands or with sticks.

A similar single-headed drum is found in Malaya, especially in North Celebes. Here again it is used by Mohammedans in their mosques. Kaudern says that it "seems to have a rather wide range outside Celebes" (5). This instrument is normally made from wood, but small ones, used generally as children's toys, are made from bamboo in north-east Celebes. Of these bamboo toy drums Kaudern suggests that "they may possibly be a remainder of an earlier type of drum, at present not in use, having declined into a mere toy drum" (6). I have introduced this point because of the fact that the old Hottentot drum, seen by Burchell in 1812 in the hands of Bushmen, was made by stretching a skin over a *bambus*, or milk container (7). Now the word *bambus* is neither Hottentot nor Bushman, but is more likely to be of Malay origin. Be that as it may, the */khais* of the Korana Hottentots was a single-headed cylindrical drum beaten by the hands (8). It was, however, closed at the lower end, since it was made from a milk container.

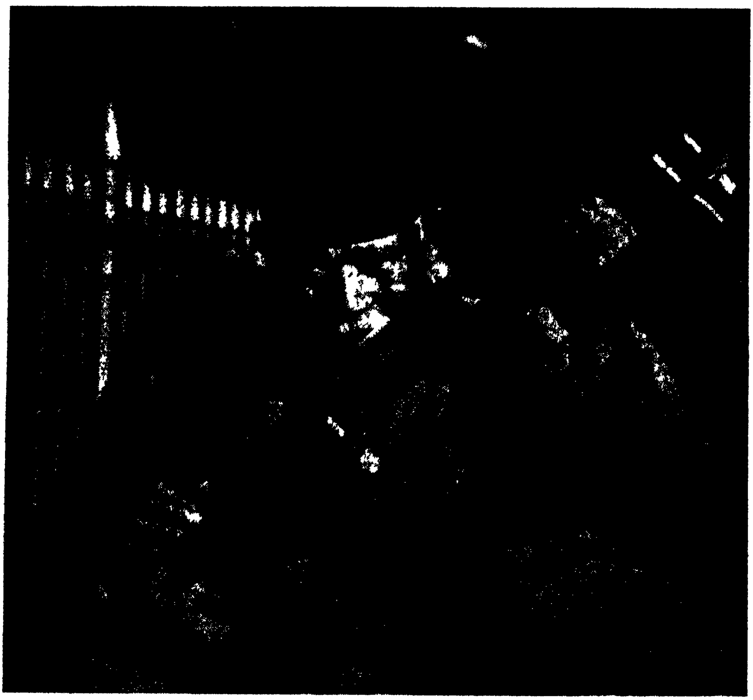
The earliest reference to such a Hottentot drum occurs in Dapper (1668), where the instrument is described as being made

by covering a *pot* with skin (9), and in this form it was observed by Dr. Andrew Smith among the Korana near the Hart's River in 1834, and drawn by his artist, Charles Bell (10). Similar pot-drums are found among the Malagasy of Madagascar (11), and I have little doubt that the early Malay slaves at the Cape also used pot-drums, for some of their remote ancestors certainly did. One of the famous Barabudur reliefs of Java, which are, of course, Indian in origin, shows a pot-drum very clearly (12).

The name *ghomma*, by which the Cape Malays call their drum, is somewhat puzzling. It appears to be related to the Bantu word *ngoma*, which is applied to some types of drum from the south to the north of Africa, and, what is still more interesting, to various dances involving the use of drums on the East coast of Africa. Even the Mohammedan dances of the Arabs at Zanzibar are called *ngoma*.

In the case of this instrument, then, we see that it is apparently of Malay origin, the Malayan type at some remote period having itself been derived from India.

2. Guitar.

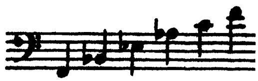


[Photo by A. Loxton.

Fig. 1.

The *guitar* used in accompanying the second class of songs to which I have referred was the regular European instrument. On the first occasion on which I heard it played it was tuned in European fashion, though a semitone higher than is customary, thus:—

Ex. 2.



On the second occasion it was tuned a semitone higher still.

The principal performer, Suleiman, who is also called Johnny Willembrug, was a little over sixty years of age. He informed me that he always tuned his intrument by ear. This would explain why there was a discrepancy between the two tunings, and also why the *guitar* was not tuned exactly as in Europe, with E as the lowest note. In order to be quite certain about this I asked Suleiman how Ras Dien, who is remembered among the Cape Malays as a great performer, tuned his instrument, and I was told that he was in the habit of using a regular *guitar* pitch-pipe with six reed-pipes, one for the pitch of each string, the lowest being E. Ras Dien also possessed a European tuning-fork.

The following illustration is a good example of the type of song accompaniment played by the Malays upon the *guitar*. It will be seen that it is European in style and very simple in character. This was to be expected, in view of the fact that the melodies of songs of this class are almost without exception European in every respect, no trace of oriental influence having survived in them.

Ex. 3. "Katoukjie"

PRECURSORS OF THE GUITAR.

Since I knew, however, that the old-time slaves at the Cape made use of a simpler stringed instrument of the *guitar* type which they apparently passed on to the Hottentots, I determined to find out what information still survived regarding it.

The instrument in question was that known as the *ramki*. This word has been incorporated into Afrikaans, where, though

it is still used for the "primitive Hottentot stringed instrument," it has acquired secondary meanings still more remote from the original interpretation attached to it. The philological aspect of the question I shall, however, leave for the moment.

In my work on the musical instruments of the South African Native peoples I attempted to trace the history of this alleged Hottentot instrument, and reproduced, in English, all the principal references to it from its first mention by Mentzel, who was at the Cape between the years 1733 and 1741. To these I would add that Lady Duff Gordon saw and described an instrument of this type in 1863, that Dr. Robert Broom saw and photographed one near Douglas between 1905 and 1910, and that two actual specimens were made for me by Cape Malays during the early months of this year (1939). The essential points contained in all the descriptions appear in the following table.

Date	Authority	Name of Instrument	Race of Performer	No. of Strings
1733-1741	Mentzel, O. F. (13)	*rarekinge* or *xguthe*	Malabar slaves	3
1781	Le Vaillant, F. (14)	*rabouquin*	Hottentot	3
1786-1801	Borcherds, P. B. (15)	*ramakiénjo*	Slaves	3
1795	Thunberg, C. P. (16)	*rabêkin*	Hottentots	3 or 4
1797-1798	Barrow, J. (17)	*gabowie*	Ghonaqua and Cape Hott.	3
1796-1805	Percival, R. (18)	*gabowie*	Hottentot (?)	4 or 5
1803-1805	Lichtenstein, H. (19)	guitar or zither	Hottentot	4
1819-1829	Moodie, J. W. D. (20)	*ramkie*	Slaves (?)	6
1823	Thompson, G. (21)	*raamakie*	Bushman	?
1834	Bell, C (22)	Hottentot guitar	Hottentot (Korana)	3
1840	Bell, C. (23)	no name	Malay (Cape)	3 (?)
1863	Duff-Gordon, L. (24)	guitar	Black Shepherd	3
1907	Schultze, L. (25)	*ramgyib* or *'gutsib*	Hottentot (Nama)	?
1905-1910	Broom, R. (26)	Native banjo	Hottentot (Korana)	3
1912	Bleek, D. F. (27)	*ramkie*	Bushman	3
1932	Kirby, P. R. (28)	*ramkie*	Bushman (Red Dunes)	4
1938	Kirby, P. R. (29)	*ra'king*	Malay (Cape)	4
1939	Kirby, P. R. (30)	*ra'king*	Malay (Cape)	1

Every one of these authorities describes or depicts an instrument of the *guitar* class. All the instruments, with the solitary exception of that described by Percival, were provided with resonators of calabash, coconut or tin covered with skin. All, with the same exception, were played *guitar* fashion by plucking the strings with the fingers. According to Percival, the performer he observed used a *plectrum*. The number of strings varied from one to six, three appearing to be the favourite number, though four runs it close.

It should also be noted that Mentzel, the first to notice the instrument, ascribed it to Malabar slaves, from whom the Hottentots copied it. His suggestion is quite possible. Up to the present I held the view that the instrument had been directly or

indirectly derived from the Portuguese *machete*, a kind of small *guitar;* the information which I recently obtained in Cape Town has, however, led me to revise that opinion. The following are the new facts that I have discovered with the help of Dr. I. D. du Plessis, of the University of Cape Town.

Suleiman, the Malay *guitar* player already referred to, informed me that long before the *guitar* came to be used by the Cape Malays they played upon a stringed instrument of their own, called *ra'king*. He himself could not play it, but he knew how it was made, and he himself drew for me a rough sketch of the shape of the instrument with its resonator of calabash, neck, four strings and tuning-pegs, and also of the manner in which the calabash was cut transversely to form the resonator. He also told me that a friend of his, named Ideroos Isaacs, was a player. I got into touch with Ideroos, who told me all that he knew about the instrument, and also promised to make a copy of one for me, which he did in a few days. His information was clear and concise.

His grandfather was a true Malay from Batavia, and his grandmother a Cape coloured woman. His grandmother lived to the age of 105, and his father to that of 83. He himself was (1939) 73 years of age. He said that he was about 17 or 18 years older than the Cape Town Metropolitan Church (which was opened in 1879); this would make him 77 or 78 years of age, and not 73 as he imagined.

Ideroos could not tell me whether either his father or grandfather ever played upon the instrument. He taught himself to play by observing the many others who played it. He was 18 when he began to play, but he had not played for about 40 years.

He obtained his first instrument from a Malay of Simonstown named Jongi Kafura. It was made from teak, and was inlaid with mother-of-pearl. The resonator was of tin, and the covering of skin from a sheep's bladder. Malays, he said, always used tins for resonators; Hottentots, calabashes. The strings were of gut made by himself from the intestines of a sheep. He lost his instrument during the influenza epidemic of 1918. He called the instrument the *ra'king*, and, although he had ceased to play it, he had heard of people in Cape Town during the last year who could still perform upon it.

The instrument which he made for me, and which is seen in his hands in Fig. 2, was constructed of ordinary deal board, roughly shaped. The resonator was of tin covered with bladder. As Ideroos could not readily secure sheep-gut he used ordinary violin E strings of double length with which to string his *ra'king*. He insisted on all four strings being of the same gauge, and very thin. A curious feature of his *ra'king* was that three of the strings stretched along the full length of the instrument, but the fourth string only went half-way, the peg to which it was attached being set in a hole in the " shoulder " of the neck.

This suggests very forcibly some relatively recent development, the American negro banjo being characterised by this feature.

Ideroos tuned the short string first of all (it was the string furthest from him when the instrument was in position for playing), and then tuned the others from it, in the order 1, 4, 2 and 3. The tuning of the four strings was as follows:—

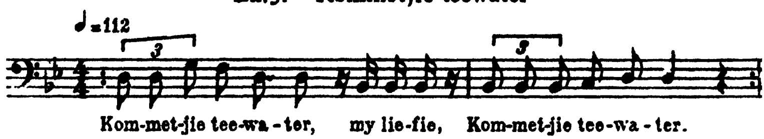
Ex. 4.

He began to "prelude" upon the *ra'king*, occasionally bending his head over it, and sweeping his chin along the strings. He said that "to improve the effect" they used to move their beards up and down the strings in that way. Moodie (1819-1829) observed the slaves using their chins to "stop" the strings (31). Bell (1834) drew a picture of a Korana woman doing the same thing (32), and I myself have seen the chin technique used by Bushmen (33), Hottentots (34), and Tswana (35) on a one-stringed instrument used by those races.

Ideroos further told me that the Malays of Cape Town used to play "little Hottentot tunes" on the instrument for dancing, they did not normally use it for singing. He insisted that it was the same type of instrument as that used by the Hottentots, but he could not say which race got it from which.

He sang one of these Hottentot tunes to me, though, as he said, they did not formerly sing words when playing for dancing; the words were "suggested" by the instrument. He picked the melody out, using the appropriate strings for it, note by note. The music was melodic, not harmonic. The *ra'king*, he said, was a different instrument from a banjo, and Ideroos demonstrated the fact. Here is the tune which he played, with the words:—

Ex. 5. "Kommetjie teewater"



Kommetjie tee water, my liefie, Kommetjie tee water.

(A little cup of tea water, my love, a little cup of tea water.)

He learned this song in the streets of Cape Town when he was a boy. It will be seen that it is admirably constructed for

the instrument, and it is interesting to notice how the accent of the tune conflicts with the accentuation of the word " tee water."

Before leaving Cape Town I was told by Dr. du Plessis, who had been searching the Malay quarter of the city, that another old Malay, having heard that Ideroos had made a *ra'king* for me and had showed me how it was played, had said to him that Isaac's information was all wrong, and that *he* could construct the proper instrument. I therefore left a series of questions for Dr. du Plessis to put to this Malay (who, curiously enough, was also called Ideroos), and to ask him to make a *ra'king* as he knew it. In due course I received the instrument and also the answers to my questions.

Ideroos Adams was 62 years of age. His grandfather was Javanese. His father and grandfather both used to play upon the *ra'king*, and he himself has known it for 50 years. He got his first instrument in his parents' house, and learned how to make it. He constructed the neck of the *ra'king*, which was thin, from deal, and used a coconut shell for a resonator. The early Malays of the Cape got these shells from Java (the coconut is not indigenous to South Africa) and the covering was made from the bladder of a cow. The string, for there was only one, was of catgut, and it was tightened by means of a tuning-peg. He last heard it played 15 years ago, and it was played *guitar* fashion, the string being plucked by the fingers. The chin was also used in playing. He did not remember the note to which the string was tuned. The instrument is shown in Fig. 2.

The *ra'king*, as he called it, was used for both dance music and song accompaniment, and women played upon it as well as men. He remembered one famous player named Gaijer Slagter. Ras Dien did not play upon it, but his father did.

[Photo by W. P. Paff.

Fig. 2.

It will be seen at once that, though the principle of both instruments is similar, they would appear to be descendants from two distinct prototypes, or perhaps, separate developments from a single prototype. Both suggestions are quite possible.

The instrument made by Ideroos Isaacs, although apparently influenced by the modern banjo, suggests by its construction and its general nature, that it is related to a type of instrument found in both Java and Celebes, India and the east coast of Africa. In Java and Celebes it is called *gamboes* (36), a name which may possibly be connected with the word *gabowie*, which was recorded in South Africa by Barrow and Percival; in India it is called

kinnari vina or *kacchapi vina* (37), while in Mombasa and Zanzibar it is known as *kinanda* (38). It also has Chinese and Japanese connections in the *biwa* (39). It should be noted that Malaya has been connected at different times with all the countries mentioned here. But in spite of these apparent connections the *gamboes* would appear to have come to Malaya from Arabia along with the Mohammedan religion (40). This instrument is also found in Madagascar (41).

On the other hand, the instrument made by Ideroos Adams corresponds closely in construction to the Arab *kemengeh* (42), although the latter has more than one string and is played by a friction bow. But I have no doubt whatever that the Arab instrument was the prototype of this Malay one; not only the design but also the etymology of the name points to this fact. Lane, in discussing the *kemengeh* (43), quotes a friend as saying that *rabab* would be "a more proper term for the instrument, being the general Arabic name for a viol." This word *rabab*, or *rebab*, is connected with the Portuguese word *rabeca*, a violin, and also with the old English term *rebeck*.

The following table shows the evolution of the South African names for the instrument.

Portuguese *rabeca pequena*, from Arabic *rabab*

rabequinha

rabouquin (1781) *rarekinge* (1733-1741) *ramakienjo* (1786-1801)

rabékin (1795)

raboochine (1797-1798)

ramkie (1819-1829); *raamakie* (1823)

ramgyib or *!gutsib* (Nama, 1907)

ra'king (Malay, 1939) *ramki* (Afrikaans, 1939)

It should be pointed out that *rabeca pequena* means a little violin. Further, that Barrow, who gives the form *raboochine* in his manuscript (17), has the alternative name *gabowie*, which may be connected with the Malay *gamboes*.

Conclusion.

The evidence shows clearly that certain types of musical instruments were imported into South Africa by the Malay slaves of former days. These types have been adopted, though to a limited extent, by some of the aboriginal peoples, notably the Hottentots. Traces of them still remain in the Cape among the descendants of the original Malays, and also in other parts of South Africa among the Hottentots and the peoples with whom they came into contact. These types of instruments can be traced to the older civilisations of India and Arabia, both of which exercised a profound influence upon the Malay Archipelago in the past.

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THE MEDICAL ASPECT OF BOXING

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With 4 Text Figures.

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In this paper, which is based on the results of a ten years' clinical and experimental investigation, an attempt is made to give a scientific analysis of the " specific " medical problems of boxing.

Only an abbreviated extract from a rather extensive collection of scientific evidence will be presented. Details, case histories, much illustrative material and a full bibliography are included in a specially prepared monograph.

Conditions Occurring During or Immediately After the Fight.

Legal Knock-outs.

The aim of a participant in a boxing match is to impair the opponent's fighting power to such an extent that he is for a period of not less than ten seconds totally incapable of continuing. The " ideal " way of achieving this aim is to " knock him out." There are four principle forms of " legal " knock outs, the most important of which is the " chin knock-out."

The Chin Knock-out.

This knock-out is caused by blows on the chin, those coming somewhat from the side and from below (" uppercuts ") being rather more effective than blows from directly in front. They result in immediate loss of consciousness, lasting for variable lengths of time.

Theories.—A number of authors have presented theories on this impressive phenomenon, many of which are devoid of a scientific basis. It has been said that the knock-out is due to a " nerve in the chin being hit;" that " the jaw is jerked backward, thus compressing the carotid arteries;" that " the jugular veins become obstructed " and that consequently " a reverse flow of blood occurs towards the brain;" that " a temporary derangement of the semi-circular canals at the back of the ear " takes place; that " the trigeminus or the vagus nerves play an important part " and that the " labyrinth is affected."

There is definite clinical evidence that a knock-out blow to the chin leads to a so-called "contre coup" phenomenon; the medulla oblongata, with a two-phasic jerk, bounces against its bony encasement. The mechanism of this occurrence is illustrated in Fig. 1. It is known that the medulla oblongata is more susceptible to trauma than any other part of the brain, and that slight injury to this region results in immediate loss of consciousness. The writer's studies have proved that the state after a chin knock-out clearly differs from the state of concussion of the brain which is better known to the neurologist.

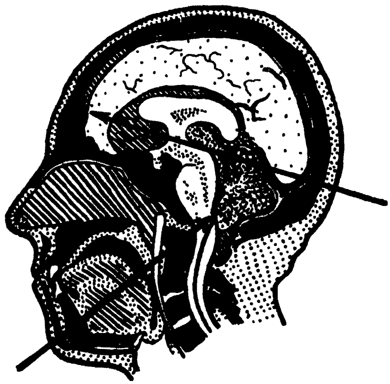

Fig. 1.

Sagittal sections through head. The two arrows indicate the directions from which blows cause contre coup effects.

Further, it is known that blows to the chin may result in the boxer's losing control over his muscles without his suffering impairment of consciousness. This reaction, which the writer has originally described as "traumatic loss of muscular tone," is a typical vestibular phenomenon, as, on theoretical grounds, was anticipated many years ago by Sir Charles Sherrington.

Supporting Clinical Evidence.

The author's contre coup theory of the chin knock-out is strongly supported by neurological experiences. It was observed that contre coup effects upon the brain only occur, as a rule, if the trauma is directed against the head from the front and below, or from behind and below. Blows or non-penetrating injuries resulting from blows coming from other directions lead to local and direct, rather than to "transmitted" effects.

Solar Plexus Knock-out.

Second in importance among boxing knock-outs are those caused by blows to the upper abdomen. We describe these phenomena as "solar plexus knock-outs." This type of knock-out is distinguished by a number of distressing sensations: first comes severe pain, localised in the upper abdomen, but often radiating far beyond the point of contact. Secondly,

the boxer has the agonising feeling of suffocation, and he is unable to breathe. Then, there are, as in the chin knock-out, frequently the peculiar symptoms of loss of muscular tone. The muscles seem to lose their strength, the boxer drops to the ground unable to regain his feet. He hears the referee counting him out, but can do nothing to overcome the temporary state of profound muscular weakness. As a rule, the boxer recovers from this acute state within a short time.

Theories.—As one might expect, this well-known occurrence has been the subject of numerous hypotheses, of which the one by Goltz, presented almost eighty years ago, is the most outstanding and the one best supported by scientific evidence. In 1863, the latter author published the results of experiments which are now considered classic. Using frogs (medium sized *rana esculenta*) he cut a small window into their chests without injuring the pericardium. This enabled him to watch their hearts beating. By tapping against the frogs' abdomens he induced the heart to beat more slowly and ultimately to stop in diastole. At the same time respiration became suspended, arterial blood pressure dropped and muscular tone decreased greatly (Fig. 2). Goltz further analysed the physiological mechanisms underlying this interesting reaction. He especially studied the part played by the nervous system.

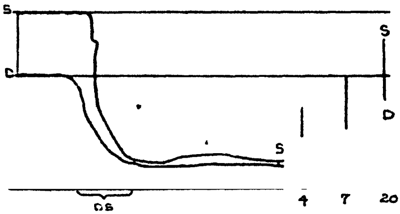

Fig. 2.

Animal experiment (dog) showing effect of irritation of solar plexus on systolic (S) and diastolic (D) blood pressure. DS. = irritation of epigastric region. The immediate decrease of blood pressure is obvious. Recovery only after more than twenty minutes.

There can be no doubt that the solar plexus knock-out in boxers is an equivalent in humans to Goltz's famous experiment: a functional nervous reaction to abdominal trauma, leading to a profound temporary impairment of autonomic integration. This state is almost always followed by spontaneous recovery.

Danger of Severe Injuries.

It is noteworthy that, contrasted with the effects of blows to the *head*, *abdominal* blows received in the boxing ring very rarely cause serious organic damage. This statement is of special importance since general surgical experience shows that abdominal blows with the ungloved fist, especially blows dealt to untrained individuals, frequently produce severe injury. In other words, the boxing glove and a trained musculature afford a considerable amount of protection.

Heart Knock-out (Concussion of the Heart).

Blows directed to the left side of the thorax, especially those against the apex of the heart, sometimes, although not frequently, cause a knock-out. A number of experienced professional boxers who were interrogated on this question, unanimously agreed that the effects of well-placed "hooks" to the heart last for a considerable period, usually for the rest of the fight. They also said that subjective experiences after heart knock-outs differ from those felt after solar plexus blows.

The medical analysis of this blow is of special importance: its results apply to a number of fatalities which have occurred in the boxing ring during recent years, after blows to the heart.

Theory.—The theoretical basis for the understanding of the heart knock-out has been elaborated by Schlomka. Between 1931 and 1933 this author carried out a well planned series of animal experiments in which he demonstrated that blows to the lower part of the anterior chest wall may provoke a variety of circulatory reactions. The heart acutely dilates, the mechanism of its beat becomes greatly disturbed, arterial blood pressure decreases, while venous pressure increases. All these reactions clearly indicate a profound disturbance of circulatory integration.

In Schlomka's animal experiments, as well as in our observations on human beings, the effects of blows to the heart were found in the majority of cases to be of short duration. In a small number of well studied instances, however, blows to the heart have caused instantaneous death in the ring. In most of those cases autopsy revealed the presence of pre-existing serious organic disease of the heart.

Carotid Sinus Knock-out.

Among experienced managers and fighters it is common knowledge that direct punches against the lateral region of the neck may lead to a knock-out. A few cases have even been studied in which blows to the side of the neck resulted in death.

The physiological mechanism of such occurrences was explained in 1923 by Hering. This investigator discovered that the carotid arteries at the level at which they branch into two powerful arms supplying face and brain with blood are surrounded by networks of specific nervous receptors (Fig. 3). These structures make the carotid sinuses the most important peripheral autonomic nervous integrators. Traumata to the carotid sinuses, such as blows with the first, may affect respiration, circulation and muscle tone and thus produce sudden collapse.

Illegal Knock-outs.

A number of punches are declared illegal. The most important blows of this kind are the "rabbit punch," directed against the back of the neck, the "kidney punch" to the body, and the blow "below the belt." With regard to the rabbit

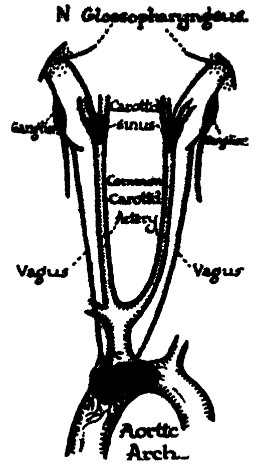

Fig. 3.

Diagrammatic presentation of anatomy of carotid sinuses. The shaded areas contain presso-receptive nerve endings. (Note functional relationship between aortic arch and carotid sinuses.)

punch, evidence is available that a certain type of blow to the back of the neck can cause serious cerebral injury, probably by driving the lower parts of the brain into the foramen occipitale magnum. The dangers of the two other " illegal " blows have frequently been over-rated. Kidney punches are altogether unavoidable in boxing, as many " legal " blows to the body are bound to affect the upper poles of the kidneys. Serious renal injuries are rare. If they occur it may be assumed that the injured organs had been diseased before the trauma. Blows " below the belt " can be painful if they hit the genital organs. However they rarely lead to permanent disability or serious injury.

Related States.

Individuals who have been unconscious for a certain period are subsequently unable to recall events or subjective experiences connected with events which have taken place during the period of unconsciousness. This condition of inability to remember is spoken of as " amnesia." The amnesia may cover only the actual period of unconsciousness. We then speak of " simple amnesia." In other cases, the amnesia may also include a period *preceding* the state of unconsciousness; this is " retrograde amnesia." Thirdly, the amnesia may further include a period *following* the state of unconsciousness; this is called " anterograde amnesia." All three of the above states are commonly observed in boxers.

Frequently it occurs that boxers, after a fight, sit in the dressing room and are unable to remember the events in the

ring, and even to say whether they won or lost. In other cases, the boxers, for a considerable period following a fight, appear to the superficial observer entirely normal, although an examination reveals that they are in a state of greatly impaired consciousness, and that they are unable to remember anything that has taken place during that time. Some authors have recently stated that an amnestic period invariably appears as a " blank," i.e., that no " productive " mental processes are superimposed upon the retrospective defect. This is not quite correct. The writer has studied a number of cases of boxers, who, during amnestic states, experienced hallucinations of an acoustic, as well as of an optic type; that fleeting moments of the amnestic period were retained in memory with the actual sensory impressions greatly altered by fantasies, and sometimes even by grotesque illusionary aberrations and by hallucinations. Another category of mental events is that of the conscious, or more frequently of the unconscious, filling of amnestic gaps of memory with fabrications. This phenomenon not infrequently leads to unjustifiable charges being raised against boxers, or even to forensic implications.

The knowledge that amnestic states occur after fights has made a deep impression upon the more responsible element among boxers. Few of them, however, have so far drawn the obvious conclusions. The majority of boxers and sportswriters regard these occurrences as interesting or sensational, and the writer has encountered old boxers who boasted that " they could fight unconscious."

Groggy.

It has been suggested that the " classic " chin knock-out is a protective reflex which renders the victim unconscious, and thus protects him from further traumatisation. Unfortunately, the remarkable resistance power to traumata of the human central nervous system often enables boxers to continue fighting after the brain has been severely injured by blows to the head. In such cases boxers act in the ring almost automatically. Their actions are conducted in the way of conditioned reflexes and are not expressions of wilful acts. Consciousness is invariably impaired, and the brain is dangerously exposed to further traumatisation. Although formally the referee has the right to break up a fight if a " groggy " boxer's condition justifies the fear of permanent impairment, use of this privilege is not often made.

More than sixty years ago, Koch and Filehne, in a series of animal experiments, showed that blows to the head, coming from various directions, produce a state of impaired consciousness very similar to that of grogginess in boxers. A multitude of cerebral and other symptoms were observed even when the strength of each individual blow did not suffice to cause serious injury. In other words, it was established that grogginess results from the super-imposition of numerous cerebral traumata

producing a peculiar concussion state of the brain. The danger of this state is not recognised among boxers.

The study of grogginess in boxers has revealed a hitherto unknown specific type of cerebral concussion which, for various reasons, has not before been observed by neurologists.

Delayed Effects.

Knock-outs, as well as states of grogginess and of amnesia after blows received in the ring, are commonly followed by delayed effects which may impair the boxer's efficiency for a considerable period. In addition, such delayed sequels indicate that blows to the head may cause permanent injury to the central nervous system. Examination of boxers 24 hours after knock-outs frequently reveal symptoms such as headache, double vision, giddiness, vomiting, nystagmus, alteration of postural reflexes and other signs pointing to the central nervous system.

Loss of Muscular Tone.

It is a common experience that following blows against chin or abdomen, boxers have the feeling as if " something had knocked their legs from under them," and collapse on the spot. Strangely enough, they do not lose consciousness, but are unable to regain their feet as they have lost control of their legs. A state of true paralysis is present, although only for a very short period. The writer has taken a special interest in the study of this traumatic condition, as he had formerly observed and described similar states in athletes occurring *spontaneously* under the influence of great physical efforts. In spite of their harmless nature, conditions of loss of muscular tone invariably make a profound impression upon the victims' minds.

Loss of muscular tone also occurs in other branches of sport, especially in wrestling, rugby, ju-jitsu and in tumbling.

Concussion of the Brain.

As was pointed out before, concussion of the brain occurs less frequently among boxers than " simple " knock-outs do. It was also indicated that the pathophysiological mechanism of the latter phenomenon is of an entirely different nature. It is doubtful if concussion of the brain can ever directly result from blows to the head received in an ordinary boxing match under regulation conditions. The few carefully investigated cases of concussion of the brain in fighters were due to additional injuries, such as are caused by collision of heads, or by the impact of a falling fighter's head on the floor, either inside the ring or beyond the ropes. The effects of concussion of the brain last longer that those of typical chin knock-outs, and are accompanied by symptoms, such as vomiting and severe headache, which do not always occur after a " pure " chin knock-out. The symptoms never subside quickly, and the condition is usually followed by a prolonged period of severe

headache, by giddiness and by a state of pronounced weakness; recovery time is invariably long, at least a week or two, more often, however, months. From the medical point of view, concussion of the brain must always be regarded as a serious injury.

Severe Injuries and Fatalities in the Ring.

Although severe injuries and fatalities in the ring are comparatively frequent occurrences, they can be treated only briefly in this paper.

Apart from common surgical conditions such as fractures and dislocations, especially of hands and arms, there are typical as well as atypical brain injuries which are responsible for permanent disablement of and for fatalities in boxers. These conditions, therefore, deserve careful study.

The writer has analysed a considerable number of case histories, among them 35 fatalities in the ring. In almost all cases, blows to the head were directly responsible for the serious sequels, although in some instances pre-existing pathological conditions or accidental occurrences played a part. There is an intrinsic factor of danger in boxing which is responsible for the many serious injuries.

Permanent Pathological Consequences of Boxing.

Punch Drunk.

It has been known for a long time that a large number of boxers, especially professionals, after several years of fighting and sparring, suffer from various symptoms which indicate a permanent impairment of their central nervous symptoms. However, not until 1928 was the attention of the medical world drawn to a more definite clinical condition called " punch drunk " in a paper by Martland. The first systematic neurological study of cases of punch drunkenness was undertaken between 1931 and 1933 by the writer.

The clinical syndrome referred to among boxers as punch-drunkenness (" punchy," " goofy," " slug happy," " cutting paper dolls " and " slug nutty ") has become so important that at the 1937 convention of the National Boxing Association of the United States of America, an imposition of one per cent. levy on all boxing-gates was voted, the proceeds to be used for building a home for punch drunk fighters.

A careful study of case histories of punch drunkenness leads to the conclusion that the repeated cerebral concussions occurring in boxers, cause multiple scattered organic lesions. The mechanism of this type of injury has been diagrammatically explained by Martland (Fig. 4). There is evidence that it is mainly the corona radiata which is affected while the cortical area usually escapes injury. This fact would also explain why epilepsy is a rare sequel to head trauma received in the ring

in contrast to general neurological experiences with head injuries otherwise received.

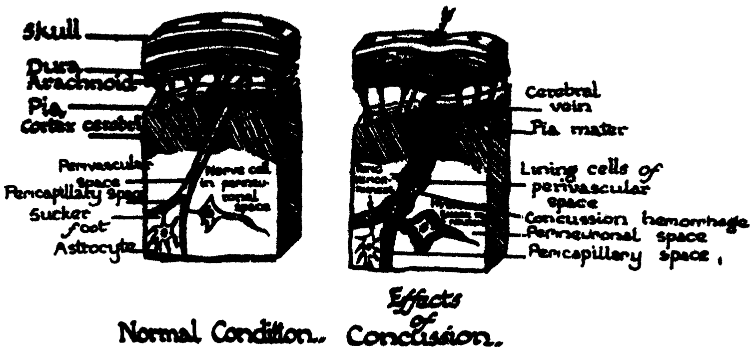

Fig. 4.

Martland's diagrammatic presentation of the pathogenetic mechanism of punch drunkenness.

The fact that punch drunkenness is due to multiple scattered organic cerebral lesions explains why the clinical picture varies from case to case. On the other hand, the predilection of the sub-cortical regions to injury explains why certain symptoms, such as encephalitic-like disturbances of motor functions, increase of muscular tone, ocular symptoms and emotional and character changes dominate the clinical picture. A punch drunk boxer's gait becomes gradually impaired, he often drags one leg, his speech becomes thick and halting and a fine or coarse tremor develops. He, therefore, often appears to the superficial observer to be in a state of intoxication. This erroneous impression explains the popular choice of the term "punch drunk."

There can be no doubt that the entire personality of a punch drunk boxer undergoes profound changes. His memory for recent events declines, and he is, therefore, likely to ask the same question over and over again; his intelligence gradually deteriorates; he becomes emotionally unstable and is often unable to earn a living in a civil occupation. Thus he will keep on trying to obtain contracts to fight or act as sparring partner and expose his diseased central nervous system to further traumatisation. The final results are often pathetic. Numerous well-known novelists have used this subject in their plots.

It appears that punch-drunkenness is not a disease of a progressive nature. The condition tends to remain stationary when boxing is discontinued. However, there will be no substantial improvement and full recovery is not possible.

Undoubtedly, the number of brains which are permanently damaged through boxing is considerably greater than might appear on account of a study of the incidence of punch drunkenness. Significantly, it is the exception rather than the rule that

boxers who take up their sport at a very early age, become successful later on. An enquiry made by the writer revealed that successful child boxers practically never develop into champions. "They all grow stale before long," said a greatly experienced coach. He added that it is the "fighter" as contrasted with the "boxer," the "emotional" rather than the "scientific" man, whose performances in the ring deteriorate quickly. Undoubtedly such observations suggest that the damage to the central nervous system outweighs the general advantages of physical training in boxing. In no other sport have similar experiences been collected. The amateur boxing authorities in Johannesburg have recently made the laudable attempt to improve this rather deplorable state of affairs by raising the age limit for participants in junior boxing tournaments. Naturally, it is impossible that anything short of elimination of the cause, i.e., the abolition of boxing, can obviate the dangers.

Conclusion.

Boxing is an intrinsically dangerous, and therefore, the writer contends, an undesirable form of physical education. Brain injuries are unavoidable in boxing. They are actually routine occurrences. It must further be realised that the fundamentally healthy tendency of young people and of sportsmen to disregard and conceal pain, physical disabilities and illness, makes it virtually impossible for a boxer to recover from head injuries received in the ring—if we assume that full recovery from head injuries is ever possible.

Anticipating a common argument advanced against his contention that boxing should be prohibited in educational institutions, the writer would like to state that there is no evidence to support the frequent allegation that boxing is a particularly valuable method of "developing character, determination and personality." On the contrary, there can be no doubt that boxing offers an opportunity to many asocial individuals to indulge in activities which are condemned normally in society; that the refusal to realise the dangers of boxing is responsible for many a boxer's life being spoiled" ("The boxing profession drips with innocent blood—the blood of fools," Kersh), that boxing exerts a brutalising influence on spectators, and that it appeals to the lowest human instincts.

The author recently discovered a copy of the "Natal Advertiser" of 4th July, 1888, which contained the following paragraph.

"An objectionable feature of English sporting life has been introduced into the Transvaal, namely, prize fights What is popularly described as a brutal and bloody affair of this kind took place in Johannesburg a few days ago. Two men known as Spalding and Yorky, were the champions. The type of humanity which can find pleasure in witnessing two men batter each other about as much as possible to gain a money prize must be a very low one."

THE NEED FOR THE INVESTIGATION AND THE CONSERVATION OF HUMAN RESOURCES IN SOUTH AFRICA

Organisers of the Symposium:

DR. E. G. MALHERBE,

Formerly Director, National Bureau of Educational and Social Research, Pretoria, now Director of Census, Union of South Africa

AND

PROFESSOR JOHN PHILLIPS,

University of the Witwatersrand, Johannesburg.

CONTENTS.

South African Journal of Science, *Vol. XXXVI, pp. 500-501, December, 1939.*

(1)—INTRODUCTORY REMARKS

BY

The Hon. J. H. Hofmeyr, M.P.

Ladies and Gentlemen,

Last night I addressed a political meeting at Grahamstown. To-morrow I am due to open the Native Agricultural Show at Umtata. To-day, in response to an invitation, which as one of your ex-Presidents I sincerely appreciate, I am presiding over this Symposium. I think there is some significance in the collocation of my functions and activities.

This Symposium follows on the very successful Symposium held last year at Pietermaritzburg. It dealt, you will remember, with the need for the conservation of South Africa's natural resources. It was an outstanding success, but it left behind a sense of incompleteness. It was felt that it was incomplete, because a discussion of our human resources had been left out. That is why this Symposium has been arranged. But the nearer you get to man, the more inescapable do man's prejudices and sentiments become, the nearer do you get to the raw material of politics. To-day we shall be touching—one cannot avoid it—on political questions, and ultimately the need for action which our consideration will reveal will be mostly a need for political action. Well, when a politician in this politics-ridden country of ours is asked to preside on such an occasion, quite a lot may happen. That at least was the opinion of the local broadcasting authorities, who sought assurances that I would say nothing here which would not pass muster with what Kipling would describe as a " political harumphrodite." You have, of course, asked me to preside here, not as a politician but as an ex-President of the Association. The politician, my McConachie, I left behind at Grahamstown last night. I am happy to-day to be among scientists, and in so far as you will as scientists be intruding on political matters, I can only welcome that fact. Politics would be all the better for a little more of the scientific spirit. By a pathetic misuse of language the politician prides himself on being a realist. The true realist is the scientist who is concerned with facts and who has no desire to dwell in that world of opinion, of sentiments, and of prejudices, which is the normal habitat of the politician.

To-morrow I shall be in the Transkei, in the heart of our greatest native area, at an Agricultural Show where one will be able to see something of what is being done to combat

malnutrition among the native peoples. That is enough to ensure my not forgetting to remind you that we are concerned here just as much with our human resources among non-Europeans as among Europeans. Let me be brutally concrete If there were no gold mining industry, there would be little, if anything, in the way of a South African Association for the Advancement of Science. It is most improbable that we would be meeting here to-day. But if South Africa had no resources of native labour, there would be little, if anything, in the way of a gold mining industry. A very important part of our consideration to-day must concern itself with the part played in our national, economic and social structure by the non-European peoples of this land and with the inter-relation and the consequences of the inter-relation of the European and non-European elements.

I have only one thing more to say at this stage—I hope we are not going to confine ourselves too narrowly to the subject of the Symposium as announced. I am not too happy about the phrasing of it: "The Need for the Investigation and Conservation of Human Resources in South Africa." Compare it with last year's subject: "The Need for the Conservation of the Natural Resources of South Africa." The suggestion is that the two needs, human resources and natural resources, are on the same footing. It at least lends itself to the interpretation that we are simply concerned with human beings as part of our natural resources as means to ends. Of course, that would be wrong Every human being endowed with personality is an end in himself; every human being, whatever his social status or the colour of his skin, is capable of making a worth-while contribution to the community. No human being is just a producer or a consumer or just cannon-fodder or even just a soul to be saved As we consider our human resources, it is in relation to the place of human beings in the good society that we must do so It is in that spirit that I now declare this Symposium open and ask Dr. Cluver to address you.

South African Journal of Science, *Vol. XXXVI, pp. 502-514, December, 1939.*

(2)—POPULATION AND HEALTH ASPECTS

BY

E. H. Cluver,

Secretary for Public Health, Union of South Africa.

Read 5 July, 1940.

The hygienist views the problem of conserving human resources from two aspects—fertility of the population and life destroying agencies; he has to consider the factors operating on births and deaths.

Vital Statistics.

We have to deal in the Union with a total population of ten million, composed of two million Europeans, seven million Bantus and one million Asiatics and other coloureds. The actual figures as estimated from data supplied by the Director of Census and Statistics are shown in Table I.

Table 1—*Estimated Population of the Union at 30th June, 1939.*

European	2,107,100
Bantu	7,054,500
Asiatic	232,500
Mixed and Other Coloured	821,300
Total	10,215,400

It is only regarding the small European section of this population that vital statistics have hitherto been systematically collected. Only of this section, therefore, are we justified in making certain statistical deductions which have a bearing on our problem.

In many of the countries of Europe the falling birth-rate has to a considerable extent been compensated by a falling death-rate. This compensation must of necessity be of a temporary nature since the lowering death-rate results in more persons reaching the later relatively non-fertile decades. If the supply of young females is cut off, saving of the lives of females beyond the child-bearing age cannot for long prevent a fall in the population. In most western European countries the present natural increase of population, i.e. the excess of births over deaths, is not indicative of a continuance of population growth The low birth- and death-rates are leading to a steadily increasing average age constitution from which inevitably follows a decreas-

ing reproductive capacity. If the present tendencies continue, the population will soon enter upon a period of rapidly falling populations and ultimate extinction.

In South Africa the natural increase rate for Europeans is still high compared with that of other countries. This is to be attributed to our relatively high birth-rate. Both these rates are steadily falling as will be seen from Table II. Our death-rate on the other hand is not falling appreciably.

TABLE II—*Natural Increase or Survival Rate among Europeans in the Union, per 1,000 of the Population.*

Year.	Birth-rate.	Death-rate.	Natural Increase.
1911	32·2	10·4	21·8
1912	32·2	10·3	21·9
1913	31·7	10·3	21·4
1914	30·2	9·5	20·7
1915	29·3	10·3	19·0
1916	29·3	10·2	19·1
1917	29·0	10·3	18·7
1918	28·6	17·2	11·4
1919	26·9	11·9	15·0
1920	29·0	11·1	17·9
1921	28·4	10·4	18·0
1922	27·5	9·5	18·0
1923	26·7	9·8	16·9
1924	26·3	9·6	16·7
1925	26·5	9·4	17·1
1926	26·2	9·6	16·6
1927	25·9	9·7	16·2
1928	25·8	10·2	15·6
1929	26·1	9·5	16·6
1930	26·4	9·7	16·7
1931	25·4	9·4	16·0
1932	24·2	10·0	14·2
1933	23·5	9·3	14·2
1934	23·4	9·7	13·7
1935	24·2	10·5	13·7
1936	24·2	9·6	14·6
1937	24·9	10·1	14·8
1938	20·0	9·5	15·5

In 1911 the birth-rate was 32·2 and the death-rate 10·4 of the population. By 1938 the birth-rate had dropped to 25, while the death-rate remained virtually stationary at 9·5. The natural increase during that period therefore dropped from 21·8 to 15·5 per 1,000. From Table III it will be observed that in spite of our stationary death-rate our rate of natural increase still remains surprisingly high in comparison with countries of a European civilisation. In France, for example, the population has become stationary, the birth- and death-rates being the same.

TABLE III—*Comparison of Birth, Death and Natural Increase Rates among Europeans in the Union with other Countries. Average Rates for Three-yearly Periods (based on latest available information).*

Country.	Birth-rate.	Death-rate.	Natural Increase.
Union of South Africa ...	24·7	9·7	15·0
Holland	20·3	8·6	11·7
Portugal	28·3	16·7	11·6
Canada	20·2	9·5	10·07
Italy	23·0	13·6	9·4
New Zealand	16·4	8·3	8·1
Australia	16·7	9·4	7·3
United States of America	16·9	11·1	5·8
Germany	18·6	11·5	7·1
England and Wales ...	14·8	11·9	2·9
France	15·4	15·4	—

Can our white population be saved from a falling rate of natural increase, which later becoming a decrease, will in time cause a catastrophic fall in the size of the population as larger and larger proportions of the population are to be found in the later less fertile ages? The answer depends on the extent to which we can control the two factors concerned. Can the fall in birth-rate be arrested? There can be no doubt that our death-rate is too high.

BIRTH-RATES.

Many reasons have been advanced for the apparent diminishing fertility of peoples of Western European origin. Whether an inherent physiological factor is involved is open to doubt. If only sociological factors were concerned, these might conceivably be combated, as is being attempted in totalitarian states. Thus earlier marriage might be encouraged by financial assistance or patriotic appeal. In South Africa at any rate it

does not seem that the falling birth-rate can be attributed to delayed marriage.

The published statistics of our European population do not indicate any striking change during recent years in the age at which marriage ordinarily occurs. The age group 20-24 has remained undisturbed as the period at which European females in South Africa commonly marry. Physiological and pathological factors may also with reasonable safety be ruled out. No physiological change is taking place in the European stocks, attributable for example to the local climate, which suggests a lessened amount or activity of reproductive tissues. There has also not been a statistically important increase in those diseases, notably the venereal diseases, which often result in infertility of the patient, certainly not among the European portion of the population.

In the absence of such factors we are forced to attribute the fall in birth-rate largely to an increasing sophistication. With information about birth-control easily obtainable and equipment readily purchasable, it is not to be wondered at that the economic demands of our times and the unpleasantness and inconvenience of child-bearing result in married couples increasingly avoiding conception. Children are expensive to rear in modern times; this lessens the funds available for purchasing amusement. The fact that the discomforts associated with the long period of human pregnancy and the restricted life of the nursing woman are avoidable by a little forethought is quite certainly resulting in conception being deliberately avoided.

If a larger population is needed in South Africa—and one can assume general agreement as to the desirability of a larger *white* population—then immediate attention must be given to the supply end of our human material. Since essentially sociologic and economic factors are involved in attempts to increase birth-rate, I shall leave the discussion of these to other contributors to this symposium The hygienist is, however, concerned with the grave and unnecessary wastage of life among infants actually born. The causes and methods of prevention of infant mortality must therefore be investigated.

INFANT MORTALITY.

The infant mortality rate is conventionally expressed as the number of deaths of infants under twelve months of age per 1,000 births during the year. This rate, as shown in Table IV, is falling steadily among Europeans in the Union. It fell from 82 in 1919 to 52 in 1938. It is still, however, disgracefully high considering that practically all these deaths are preventable by hygienic measures.

TABLE IV—*Infantile Mortality Rate of Europeans in the Union of South Africa, i.e. Death-rate of Children under One Year per 1,000 Births.*

Year.	Total European Births Registered.	Deaths of European Children under One Year.	Death-rate per 1,000 Births.
1919	39,724	3,250	81·81
1920	43,445	3,913	90·07
1921	43,302	3,338	77·09
1922	42,832	3,123	72·91
1923	42,181	3,139	74·42
1924	42,346	3,122	73·73
1925	43,411	2,969	68·39
1926	43,876	2,844	64·82
1927	44,347	3,132	70·63
1928	44,813	3.159	70·49
1929	46.219	2,968	64·22
1930	47,534	3,177	66·84
1931	46.423	2,928	63·07
1932	44,944	3,082	68·57
1933	44,519	2,716	61·01
1934	44.878	2,728	60·79
1935	47,717	2,997	62·81
1936	48.630	2,872	59·06
1937	50,878	2,878	56·57
1938	52,065	2,691	51·69

That these figures can be lowered is demonstrated by the results of active hygienic campaigns in other progressive and, in this respect, more enlightened countries. Table V shows infant mortality rates for three-yearly periods for various countries. South Africa with an infantile mortality rate of 56 comes out very badly in a comparison with New Zealand where the rate is only 32. It would be very much worse if a figure for the whole population including the Bantus were available. Our position would then certainly fall well below that of Portugal.

Even 32 is a high figure. In the Union in the high social strata the figure is practically zero. The number of infants born to healthy parents with congenital lesions preventing their survival for twelve months is negligible. Table VI shows the causes of death given by medical practitioners for 2,872 European infants who died in the Union during the year 1936. It will be observed that in only 430 of the cases was death attributed

to premature birth, congenital debility and malformations. Most of these deaths were not due to inherent physiological causes. The term "congenital" includes, for example, the results of syphilis in the mother and other preventable conditions.

TABLE V—*Infantile Mortality Rates: Europeans in the Union compared with other Countries. Average Rates for Three-yearly Periods (based on latest available information).*

New Zealand	32
Australia	42
Holland	41
England and Wales	58
Union of South Africa	56
Canada	70
France	68
Germany	67
Belgium	84
Italy	100
Lithuania	139
Portugal	147

TABLE VI—*Causes of Death of European Infants in the Union in 1936.*

Cause.	No. of Cases.
Diarrhœa and enteritis	667
Premature birth, congenital debility and malformations	430
Respiratory diseases, pneumonia, bronchitis, etc.	534
Convulsions	173
Whooping cough	178
Injury at birth	104
Influenza	24
Meningitis	29
Diseases of the ear and mastoid process	11
Syphilis	15
Measles	15
Other causes	503
Total	2,872

The great majority of the deaths of infants in the Union is the indirect result of underfeeding (in particular a shortage of milk) and other hygienic neglect. The disease mentioned on death certificates merely indicates the infection which in most cases was superimposed upon a body weakened beyond the power of resistance by malnutrition. Our larger municipalities are developing "well baby" clinics where mothers can get advice about the rearing of infants, and, what is even more important, assistance in the procuring of safe milk and milk products for feeding their too often sadly malnourished babies. These measures will rapidly lessen the number of infant deaths in our towns. We have no excuse for not attaining to the New Zealand figure of 32 even without a very great economic uplift of the lower levels of our European society. By merely attaining to the New Zealand rate the lives of 1,400 European babies could be saved annually in the Union. Having survived the hazards of infancy the bulk of these would reach maturity, becoming useful citizens, themselves able to contribute to an increase of population in the next generation. At present these 1,400 young European lives are being wasted unnecessarily. Actually, of course, if society were properly organised nearly the whole of the 3,000 European babies that now die annually could be saved. We have not even the consolation of assuming a survival of the fit. The fatal infantile ailments do not pick out those who in later life would be more likely to succumb. Malnutrition is not a method for selecting those infants who are likely to withstand the hazards of later life; nor is insanitation Those who survive these evil tests are themselves permanently weakened and are liable to become imperfect citizens likely to die prematurely.

Only the European aspect of the matter has been discussed, because figures for the non-European population in the Union as a whole are not yet available. In those towns where data have been collected the non-European infantile mortality rate is found to be extremely high. This is only to be expected when it is borne in mind that the Bantu population as a whole occupies a socio-economic position considerably below the average of that of the European. Systematic social welfare work among these people would save tens of thousands of infant lives annually. Again a large proportion of those who survive the malnutrition and insanitation of infancy and childhood are permanently damaged physically. This damage not only predisposes to early death, but also renders large numbers of them unfit for the labour we require them to do in our industries. The inevitable result is a rapidly increasing demand for hospitalisation (most of which is a costly confession of social failure) and an increasing shortage of fit labour for our mines, necessitating importation of Native labour from beyond our borders.

MATERNAL MORTALITY.

The threat to the survival of the European population in the Union by a falling birth-rate must be met not only by measures to save the lives of those actually born, but also by reducing the hazards of child-bearing to the mother. She is essential for the satisfactory rearing of her children and she is a potential mother of more children. Her own rights as a citizen need not be stressed.

We have made depressingly little advance in combating deaths in child-bed. The figures for Europeans in the Union are shown in Table VII.

TABLE VII—*Maternal Mortality Rates for Europeans in the Union: Deaths per 1,000 Live Births.*

Year	Live Berths Registered	Deaths due to Puerperal Causes				
		Number		Rates per 1,000 Live Births		
		Puerperal Sepsis	Other Puerperal Causes	Puerperal Sepsis	Other Puerperal Causes	Total Puerperal Mortality
1926	43,876	88	112	2·06	2·50	4·56
1927	44,347	101	112	2·28	2·53	4·81
1928	14,809	102	121	2·28	2·70	4·98
1929	46,219	140	103	3·03	3·23	5·25
1930	47,536	119	131	2·50	2·76	5·26
1931	46,423	116	102	2·50	2·20	4·70
1932	44·944	126	113	2·80	2·51	5·31
1933	44,519	113	101	2·54	2·27	4·81
1934	44,878	121	148	2·69	3·30	5·99
1935	47,717	119	107	2·49	2·24	4·73
1936	48·630	116	132	2·39	2·71	5·10
1937	50,878	99	124	1·94	2·44	4·38

In 1921 the death-rate in the Union for European mothers was 4·9 per 1,000 live births. In 1937 it was still 4·4. In the interval it has often risen above 5. Now deaths as a consequence of child-birth are very largely preventable if adequate and efficient ante-natal and post-natal nursing and medical services are available. Our figures, which it must be remembered deal with the favoured European section of the community only, are higher than those for the whole population of England and Wales. Since 1925 their highest figure has been 4·4 and it has been as low as 3·9; their figures in turn compare unfavourably with those of Germany, Norway, Italy, Sweden and Holland. The remedy for our very unsatisfactory state of affairs is to be sought in enlarged and improved medical and nursing services; these will

be discussed later. The recent introdution of sulphanilamids has given the profession a very potent weapon in combating puerperal sepsis.

MORBIDITY.

Most of our deaths are still due to preventable causes. This applies particularly to deaths during infancy, as has been seen. But it is true throughout life. Very few people as yet die as the result of true physiological senility. Most of them are taken off by preventable infection acting on bodies that may have been weakened during infancy and childhood by malnutrition and unhygienic conditions of living. Many of the deaths in later life are also due primarily to the results of these agencies which operated at the beginning of life.

Some 40 Europeans in the Union per 100,000 of the population die annually from tuberculosis. The figure varies, but on the whole is decreasing, though not nearly so rapidly as in the countries of Western Europe where active social and direct health measures have been introduced for combating this evil. Among our Bantu population the disease appears, if anything, to be on the increase. Only an infinitesimal number of persons appears to be inherently vulnerable to fatal attack by tuberculosis. Infection takes place mainly in the body damaged by malnutrition, particularly if the inadequate feeding occured during infancy and childhood. Add to this the fact that insanitation such as overcrowding in slums provides the most favourable conditions for spread of infection, then it becomes evident that here, too, we have a socio-economic problem. Improved medical and nursing services may help, but the high incidence of tuberculosis is primarily a result of poverty. The remedies are three-fold:—adequate supply to all infants of the protective foods, sanitary living which includes proper housing and facilities for outdoor exercise and other health habits such as sufficient sleep and removal of the infective from the healthy. It is in regard to the last of these that medical, nursing and hospital services can make their contribution. By accommodating infective patients in hospitals, clinics and settlements they are given some chance of being cured; but more important is the fact that while they are accommodated in these institutions the infection cannot spread to the outside population.

Deaths attributed to venereal diseases reflect in only a small way the destructive effect of these evils on the population. This is due to the fact that the final cause of death in these patients is often something superimposed on the real life destroying infection; also to the fact that a charitable medical profession is unwilling deliberately to give as a cause of death a condition to which a serious social stigma is attached. Nevertheless an appalling wastage of human health and life is to be attributed to these diseases. Medical services should be increased to provide for their early treatment at a time when they are highly

infectious. But the correct approach here is sociological Venereal disease almost completely disappears among communities living psychologically and physiologically satisfactory lives.'

The filth diseases like typhoid and typhus still exact a heavy toll among the lower social levels of the Union's population particularly among the Bantu. Health propaganda may lessen the spread of these diseases. But economic uplift is more important. Insanitary dwellings and surroundings which are responsible for the spread of typhoid and the associated intestinal diseases disappear when the community can afford better conditions. The lice which spread typhus would not be tolerated by persons who could afford facilities for washing and changes of clothes.

A disease for which in South Africa socio-economic factors seem in no way responsible is cancer. The increasing age of the population is resulting in an increasing incidence of this condition as a larger proportion of the population is entering the "cancer age." In 1921 the death rate among Europeans in the Union per 100,000 of the population was 69·1. It had increased by 1937 to 106·6. Here we have a strong argument for an improved medical service in the Union. A large proportion of cancer cases is completely curable if diagnosed and treated early. The growing public demand for a national institute, in which diagnostic methods can be studied and taught and where facilities for early diagnosis and treatment will be available, is worthy of support.

Malaria, which still undermines the health of thousands of Europeans and tens of thousands of Bantus in the Union, is capable of practically complete eradication if funds were made available for the extensive application of the measures known to be locally effective, including the hygienic education of the people in the affected areas. The same applies to the other parasitic diseases such as bilharziasis and taeniasis which are lowering the vitality and predisposing to early death large blocks of the populaton.

MALNUTRITION.

In the foregoing remarks frequent reference has had to be made to the undermining effects on health of diets which are unbalanced, i e. diets in which starch preponderates to the virtual exclusion of the foods rich in proteins, vitamins and minerals. The Health Organisation of the League of Nations coined the useful term "protective foods" for these essential balancing substances: Milk and milk products, eggs, fruit, vegetables and meat. These foods are relatively expensive, and it is because of the gross poverty of practically the whole of the Bantu population and a large section of the European population that most of the infants and children in the Union suffer from malnutrition. A body nourished during its period of growth mainly on starch foods, such as mealie meal, cannot develop normally and cannot

in infancy or later life offer adequate resistance to the disease germs which conditions of poverty allow to be all too abundantly present. Malnutrition in the Union can only be combated by bringing a daily supply of protective foods within the reach of all pregnant mothers, infants and children. This is a problem for economists and statesmen. The methods available have been fully discussed elsewhere. (1 and 2). They may be briefly listed here:—

1. Raising the economic status of the depressed portions of the population so that they are able to purchase these more expensive foods. The protective foods are more palatable than starch foods and more and more of them are used as the income of a family rises.

2. Provision by the State of free or subsidised protective foods. A small gesture in this direction is already being made in the provision of free milk to certain European school children and in the supply of subsidised butter.

3. Subsidising of farmers so that they can raise the protective foods more cheaply. This includes all associated measures, such as, for example, assistance in combating erosion.

4. Dietetic education of mothers and future mothers so that the best use is made of available wages; foods prepared so as to avoid waste of protective substances; and use made of otherwise neglected cheap forms of protective foods such as the many mineral and vitamin-rich indigenous and other freely growing plants in the Union.

MEDICAL SERVICES.

We come finally to a consideration of the orthodox machinery for promoting the health of the community, and we must admit at once that the contribution of the medical profession, as at present constituted, to the conservation of human resources is negligible. This is not peculiar to South Africa; it is true in varying degrees of most of the countries with Western European civilisation. Doctors in all these countries are not trained primarily to promote health and thereby to conserve human life. They are trained to promote the comfort of those already in ill-health by alleviating suffering. While their ministrations not infrequently shorten the period of suffering and may even promote cure, in only an insignificant proportion of the population as a whole do they result in a lengthening of life. With a very few notable exceptions the medical schools turn out doctors who are interested in the diagnosis and treatment of a sick individual patient, but who have little interest in and less knowledge of the procedures necessary for maintaining a high level of health in the community they serve

The small groups of physicians who in the various countries have specialised in public health and are serving in that branch

can make but little headway in the promotion of public he if the great army of general practitioners remain indifferent to this matter. It is this army which makes the personal contacts which are indispensable if the scientific discoveries regarding prevention of disease and the promotion of robust health are to be introduced into individual lives.

The medical schools in South Africa prepare students for entering "private practice," i.e. for gaining their income from that section of the community which is able to pay fees for medical services when their members become ill. This section is extremely small. Practically the whole of the Bantu population and more than half of the remaining European and coloured population are unable to pay ordinary doctor's fees. We are apparently training doctors who will only be able to make a living by serving less than one-fifth of the people. Actually we are already departing to some extent from the old-fashioned system of private practice and developing along lines of socialised medicine (3). This will become increasingly necessary if the profession in South Africa is to serve the population as a whole reasonably uniformly. It will have to be employed very largely by the Government (e.g. as district surgeons and railway medical officers) and benefit societies (e.g. those of the mines) or directly in the employ of industrial organisations (e.g the mine medical officers who tend the Bantu labourers on our gold and coal mines). To prepare doctors for such posts it is obviously desirable that they should be trained along preventive and not merely curative lines. Such doctors are not exploiting ill-health. They have every inducement to keep the portions of the population under their care healthy. But such inducement has unfortunately not been found sufficient. The medical student trained very largely in the hospital ward and operating theatre finds the drama of the individual sufferer too absorbing. He takes no thought that by confining himself to the treatment of the patient he is treating only a symptom in the social complex and neglecting other potential patients in the family of the sufferer.

Space would not permit of a discussion of the reorganisation which would be necessary in our medical schools if our future practitioners are to be of real value in conserving human resources. I have done this elsewhere. (4 and 5). There is a growing demand for such reorganisation. The Committee on Medical Training in South Africa expressed itself strongly in favour of introducing the preventive idea at all stages of the course (6). The Medical School of the University of the Witwatersrand is at present investigating the possibility of altering the course for medical students in such a way that its graduates will better carry out what should be the real functions of the profession.

It should be mentioned that if a physician is required to espouse the health of the whole community and not only attend

sick members he could cater for only a thousand persons. To provide adequate medical services for the whole of the population of the Union we should then need a total of 10,000 doctors. The 8,000 at present on the register would not suffice.

Summary.

We are faced by a lessening production of human life. Most of those who are born live a precarious life of low value to the State chiefly because of preventable malnutrition and insanitation during infancy and childhood. Infantile mortality in particular causes the loss of thousands of potentially useful lives because of malnutrition. This must be obviated by making the protective foods daily available to all mothers and infants. The same applies to the later ages, but not so insistently. Morbidity generally should be combated, in addition to the provision of diets balanced by protective foods, by direct attack on the agents of infection. Health improvement, and therefore preservation of life, is mainly a socio-economic problem involving improvement in man's nutrition and environment. The recognised services for combating disease and promoting health also require considerable expansion and reorganisation.

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(3)—ECONOMIC ASPECTS

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The general theme of to-day's discussions—although appearing to follow so easily and logically out of that of last year—is actually full of logical difficulties. Those who took part in last year's " Symposium " on conservation of our *natural resources*, discussed (to put it bluntly), the question: How should mankind, to its own material advantage, make the best use of the natural resources that Providence has supplied?

The problem itself is fairly direct and fairly simple. If we choose to deplete our agricultural soil and useful vegetation, and if we destroy our water sources, we can expect the most serious results for the human beings who inhabit this land of ours.

It is a business outlook, based upon our own interest.

But when we come to discuss the " conservation of South Africa's human resources," we cannot ask just as lightly " Cui bono?" (To whose advantage?).

Can it be said, for example, that humanity is useful to itself?

It is human valuations, however, that determine the conduct of men. Without being cynical, one may well ask, " What values are we here concerned with: Souls for religion? Strong young men to fight? A plentiful supply of useful workers? Or are our motives purely philanthropic?"

You must remember that I have been asked to approach the subject from the economic point of view, which to most people (quite reasonably, too) means the point of view of worldly, material interest. So the fundamental question of motive and aim puts itself.

It was wise, therefore, to choose as general title for the discussion: " The *Need* for the *Investigation* and Conservation of Human Resources."

In trying to find the unifying thought that has brought all of us here, we should probably also discover complex differences of attitude. One negative fact we shall be able to claim; namely that none of us are influenced in our opinions by any thought of personal gain. But most probably every one of us will be influenced by personal ideals or fads, as well as by group bias

or prejudice—racial, political, religious, economic. And that is all to the good for the purpose of this meeting.

One of the more hopeful signs of the disturbed times we are living in, is the growth of the feeling that the community counts for more than the individual, that the individual passes by but the nation remains.

Our outlook has changed greatly from that of the "laisser faire" economists of the last century, with their optimistic moral approval of the "acquisitive spirit," of the individual's striving after personal gain.

We have learned to look upon a social group, and particularly the national and geographical unit, as a definite organism, with a life of its own, standing for far more than the mere aggregate of the individuals that form it.

But sadly we have to realise that South Africa's population is very far removed from organic unity.

What are the Union's human resources?

The 1936 Census showed a total population of just over 9½ million persons, all told.

Out of these 9½ millions, just over 2,000,000 were persons of European descent, while more than 6½ million belonged to the South African group of Bantu tribes.

Nearly 21 per cent. of the population may be taken as "White," nearly 69 per cent. as "Native" (i.e., Bantu). Of the remaining 10 per cent. (also non-European) nearly four-fifths belong to the so-called "Coloured" group, while the rest (mainly Indians) are classed as "Asiatic."

The category "Coloured" is a very motley but convenient census makeshift. It includes the "Cape Malays" (themselves predominantly of Asiatic origin), as well as the last remnants of the aboriginal Bushmen and Hottentots, the descendants of Asiatic and African slaves, and a large number of persons of various blood mixture. And yet the "Coloured" group, viewed as a social group, shows considerable unity—perhaps more even than the European. Its members have all assimilated, in the main, European ways of life; they form a relatively solid block in the Western and Southern Cape Province (although a growing Bantu intrusion into their historical territory is pressing upon them); they are on the whole a landless class; and they have been predominantly Afrikaans-speaking ever since the 18th century.

While we do here see a group of very mixed racial composition which has reached a measure of organic social unity, this does not point to a similar possibility for all the various racial groups of our total population. Broadly speaking, the "Coloured" group was welded into a sort of unity by the slavery tradition of the 18th and early 19th century. It is not possible to create similar historical forces artificially.

The "Asiatic" group, chiefly concentrated in Natal and itself far from uniform, will probably have to be accepted as an extraneous element, rather less serious from a population point of view, because of the small percentage it represents.

We are therefore chiefly concerned with the Bantu, the European and the Coloured groups, representing respectively 69, 21 and 8 per cent. of the total population of the Union.

From the point of view of evolution, economic and social evolution, and disregarding for a while the question of race, we have, however, to consider a greater number of social strata (if one may use this term). Ignoring the primitive economy of the last few Bushmen, living on what food they can hunt for, and also of small Hottentot groups whose stage of economic development is only a little higher, we can still show in the Union almost the whole range of historical forms of industry, from the primitive stage of the Bantu in the more secluded corners to the most modern forms of capitalist money economy in our mining and commercial cities.

Not more than 40 years ago a considerable part even of the Afrikaner farmers of the interior led a life which (speaking in terms of economic evolution) greatly resembled rural life in mediæval Europe. Market production and a money outlook had hardly begun to touch the farm.

The two main groups of the European population are to-day, however, meeting more and more on common ground—perhaps most strikingly in that of sport, the professions and the public service. Nevertheless, it is not generally realised that even when meeting on such common ground, representatives of the two sections often have a different background and different roots. Urban, commercial, industrial traditions, on the whole, form the background of dominant British mentality, while behind the Afrikaner there is the tradition of the veld and the soil, and of the freedom of the older subsistence husbandry.

Among the Bantu, also, different strata, representing different stages of economic evolution, can be distinguished. Excluding the very small group of those who have attained to professional status, we have at the one end those for whom the tribal *nexus* practically does not exist any more; at the other end those for whom tribal law and custom are still in full force.

Personally, I feel convinced—although I cannot prove it—that the entirely "detribalised" Bantu are not as numerous as many people, especially urban social workers among the natives, often imagine. Nearly always there remains a desire to return to their own tribal life.

Here again, there seems to be a difference, in all honesty, among Europeans interested in the social and spiritual welfare of the native, as between the urban (and mainly British) outlook and that of their Afrikaner colleagues.

Probably both, the one arguing from the more or less Europeanised native, the other from the historical rural native, are liable to errors of judgment. Seeing, however, that more than 5 million of the 6½ million Bantu in the Union were enumerated as living on farms and in native areas alone, there is strong reason for caution in arguing from the other end.

All this may seem a somewhat long introduction. But it is highly desirable to know what constitutes our "human resources" before we start planning what to do with them.

Probably all of us would agree in the abstract to the high ideal of "the greatest possible good for the greatest possible number." But in practice, and faced by the diversity of the various groups (from the point of view both of race and of economic evolution) in our social structure, who is to assume the responsibility of deciding what is "good" for all, or even for the greater number?

It is in every way an excellent arrangement that this discussion should have been introduced by Dr. Cluver's address on the health aspect. For there we have the least controversial side of our problem, where all sensible people will admit the need of general national planning by a central authority.

We could almost say that health is, in a way, still one of the "natural resources" or gifts of nature.

All sane and thinking persons in the Union realise that the spread of dangerous disease amongst any one section of the community could easily reach their own home. They realise, too, the harmful effect of disease on the productivity of labour, and that a high proportion of physically defective persons imposes upon those who do render useful service to the community the additional burden of providing for those who can provide for themselves only partly or not at all.

And yet, I dare say, the Secretary for Public Health could tell us of instances in our own and in other countries where the most essential measures have been held up as much by indifference as by appeal to the sacred rights of liberty.

While the present company is unlikely to differ as to the universal interest of all classes of our population in effective measures of public health control, it is very improbable that even this small gathering would agree unanimously to certain basic principles of social policy in the economic field, as being the best to serve the interests of our whole population, considered as an entity.

Assuming, however, that we are in general agreement in respect of the first word of the old jingle "healthy, wealthy and wise," I would suggest a similar approach to the second. If we take the word "wealth" in its older and wider meaning of well-being or welfare, are we able to agree on some sort of common premises?

Most thinking persons would concede that in any community thrown together by fate it is a waste of energy to pull in different directions; and that unity of purpose among the various component groups of our population would be a fine thing.

As in the case of human disease, most people would desire the social body to be free from latent ills and sores which might break out and spread. Going further, and thinking particularly of the more backward groups of our population, most of us would also admit that unrest, sullen resentment or an active spirit of revolt, created by a feeling of having no scope for progress and self-development, must hamper general peaceful advance. Even from the point of view of our own material self-interest, most of us would admit that a degenerating and poverty-stricken Bantu population (the main group concerned) must be less useful to the country, both as workers and as buyers of the products of farm and factory.

Still, this would not bring us much nearer to agreement as to the actual measures to be employed.

It is the Bantu who form the greatest problem.

With moderation, sympathy and good sense on either side a *modus vivendi* between Europeans and the Coloured group should be workable. Fifty years ago, it had been reached in the Cape Western Province more nearly than would appear to be the case to-day.

Cory tells us that in Exeter Hall the Kaffirs on the Cape Eastern Frontier were once called "Black Scotchmen." One feels curious to know what cross South Briton invented the simile. I have often wondered, Mr. Chairman, if it was because the Kaffirs didn't wear trousers.

To many of those early missionaries, Christianity included all the approved ways of their own little parish. And so trousers were a symbol, the symbol of Christian life and the respectability of the early 19th century—greatly to the benefit, no doubt, of the trader.

With clearer insight into the comparative aspect of the history of civilisation, our generation would probably not coin such a phrase. But I confess for myself, even while admitting the value of greater organic cohesion between different groups of our South African social structure, that I could not face the possibility of a structure in which our basic heritage of Western European civilisation would have to be sacrificed to any extent in order to reach that end. The inevitable course of history may some day prove this to have been futile sentimentality. And yet, if we lightly gave away any of the essentials of our own cultural tradition, we should be unfaithful to ourselves, and therefore not fit to take a share in shaping the future of this, our country.

Similarly, if we tried to mould the 6½ million Bantu into imitation Europeans, we would be producing not merely sorrow-

ful creatures, but most probably a dangerous and dissatisfied rabble.

In the economic field, however, taking each group or class as we find it, there would appear to be opportunities of achieving a valuable measure of organic co-ordination amongst them. A young country is often impatient, like a child. But if we could, even by slow progress, succeed in bringing about greater economic harmony of interests, and the gradual organic integration, especially of the Bantu into the whole economic structure (at present directed almost entirely by white men), some of our most serious social problems would be quieted for generations. Our country would have breathing-space for other tasks. Social unrest in the mass is mostly the result of a sense of economic frustration.

But never would clear and dispassionate search for the truth, and courageous action, be more needed than here. One only fears that our present parliamentary system could not rise to this responsibility.

Unfortunately our " Native Problem " has so largely attracted sentimentalists (both *pro* and *con*), quacks and axe-grinders.

I knew a man who was, by many, looked upon as an authority on " the psychology of the Native." Perhaps his chief asset was that he had collected a stock of anecdotes, often striking and amusing, to illustrate " how the Native mind works." As I am of an unbelieving disposition, particularly with men who always have a pack of quotations, facts and figures up their sleeve, I asked another authority, who had actually grown up amongst a Bantu tribe and (being an educated man) could speak their language more correctly than most of them could. His opinion was: "That man really knows a great deal about the Natives But he does not know the Natives."

Among fallacies too often accepted— and therefore a hindrance to right judgment—I may mention one or two. It is usually stated that " the Native is a peasant." We might concede that, as a race, they live a peasant life. But, like the Teutonic tribes at a similar stage of evolution, as described by Tacitus, they left the tillage of the fields to the women; while the men, apart from hunting and fighting, were pastoralists with semi-nomadic inclinations. Even to-day, many tribal Natives look upon crop production as woman's work. It is only when oxen are used with the plough, that the cattle-owner condescends to take a hand. There is thus a tragical duality at the roots of Native agriculture.

Another mistake is that the West Indies or the United States of America can teach us how to deal with our Natives. We can undoubtedly learn very much; but, as direct example, only with regard to the Cape Coloured people. For like these, the so-called Negroes are a mixed race, descended from slaves, who

have lost their language and all tribal law and tradition and habitation.

All loose thinking of this kind will have to be avoided if we are to base any policy on the true facts. Even more will racial prejudice on our part—which seems unfortunately to be growing stronger as the Native worker is more and more competing against the unskilled white man on the labour market—have to be discounted.

It was European rule and economic organisation that gradually put an end to famine and murderous warfare among the Bantu, so that they began to increase rapidly. When new wants were acquired and when their restricted land, wastefully used, could no longer support the growing numbers all the year, they became a welcome source of labour for modern industry.

Soon, however, a somewhat similar process of rural exodus set in amongst the white population, often aggravated by the large numbers of native families cheaply offering their joint service to European landowners.

Both phenomena are largely the result of the destructive use of land resources. Both streams are demanding employment in our industrial system. Special preferential treatment of the unskilled white man by the State, justifiable at one stage, cannot be continued indefinitely. It is not only an expensive palliative, which insidiously saps the self-reliance of the white man, but its efficacy is rapidly disappearing.

More permanent arrangements will have to be found; for the Native, until recently nearly always a temporary and occasional worker, is being forced into regular wage-earning industry. Instead of excluding him from certain avenues of employment for the sake of the white man needing continuous work, we are now faced by the necessity of devising an industrial system in which both can be organically absorbed—taking into consideration aptitude, needs, tradition, and even historical South African prejudice.

No country can afford to lose the valuable attributes of a rural population rooted in the soil. It can least afford it if this means a break with history and tradition. To-day we have to choose between giving the Native wider access to our secondary industry, or allowing him gradually to displace the white man as actual producer on our farms. There is every reason to believe that the Bantu are excellently suited to many operations in modern mechanised industry; and it should be possible to organise special branches of work for them.

Our whole national economy has developed in a haphazard fashion, and its organic balance, as between agriculture, mining and secondary industry, is undoubtedly defective. Gold mining, for instance, in spite of its undoubted contributions to our economic development and economic stability, is a clear example. It need only be pointed out that in the mining for precious

minerals (gold, diamonds) the industrial process is ended as soon as the mineral is obtained and for sale. The recovery of coal and other non-precious minerals, on the other hand, in a well-balanced economic organism, merely marks the beginning of a wide-spread process of production.

In our agriculture, too, the commercial and speculative outlook of producing marketable commodities (largely to the exclusion of production for the needs of the farm household) has become too dominant, and has certainly aggravated the effects of declining oversea prices.

Organic re-adjustment of our present industrial system to the real circumstances of our country—its natural and its human wealth and limitations—is the great economic and social task claiming our attention to-day; for our social and economic problems are practically all inter-connected.

Again I wish to stress, however, that patient research, clear thinking and courageous action will be needed. There is no sudden and miraculous panacea. Sacrifice may have to be asked from all of us; but the consciousness of common sacrifice for the good of all has more unifying power than the argument of the personal benefits we enjoy, so fondly used by most politicians.

There is an Afrikaans saying, " Vlug is 'n goeie ding, maar jy moet betyds beginne!" (Running away is a good thing, but you have to start betimes). I am not here pleading a policy of surrender, but pleading for a brave and confident resolve to try and find new roads, in the spirit of testing and, if need be, discarding old beliefs. "Maar ons moet betyds beginne!" The sooner we begin, the better.

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(4)—SOCIOLOGICAL ASPECTS: WITH SPECIAL REFERENCE TO PREVENTIVE MEASURES THROUGH SOCIAL WORK

BY

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Read 5 July, 1939.

The idea of human resources is sociologically incomplete, save for a slave society. Human beings are consumers as well as producers, ends as well as means. An Augustine among us might plead: " Not resources, but purposes."

Not that there is anything new in the utilitarian view of human beings. An ancient piece of political wisdom asserts: "In the multitude of people is the king's honour; but in the want of people is the destruction of the prince." The prince's safety, honour, and welfare have usually depended upon his subjects in their character, not as persons valuable in themselves, but as economic and military resources. It is this that gives point to the account of the origin and consequences of King David's census.

It is important to link a resource with its purpose, in the first place because we cannot assess or even define a resource apart from its purpose. There is no such thing as a generic resource. Human qualities which are valuable in industry may be useless or embarrassing in warfare. In the second place, it is desirable to emphasise that human beings, if resources, are resources for human ends. It is this paradox that distinguishes the Human Resource from the Natural.

This second point has a markedly practical bearing upon a paper like the present. Additional quantity or improved quality is never held desirable *ad infinitum* in any resource. The additional value obtained falls off and is at some point or other offset by additional cost. Wise outlay is not carried beyond this point. But where human resources are concerned, the attitudes and interests *of the " resources " themselves* introduce a further factor into the equation which it is the task of social policy to solve.

The bearing of this upon the present symposium is evident in connection with population. Additions to numbers are *prima facie* additions to resources. Considered solely as resources, the

additions should cease at the point where their cost balances their value in terms of the purpose for which they are resources. But there is no warrant for defining this point as the social optimum. For various reasons, human beings may desire to be part of a smaller or larger population than that which would maximise production or *Macht*. Similar considerations apply to the *qualities* of a population.

What are the human resources of the Union? Numbering the people is a very rough-and-ready method of measurement. An obvious refinement is to number their natural sub-divisions: sex groups, age groups, ethnic groups. (Joab in fact numbered only the men that drew sword.) A further refinement is to grade the members of each natural group according to their inborn and acquired qualities.

The total population of the Union at the 1936 census was 9,589,898. Considering resources only, and without reference to social optima, this figure is probably below the industrial, and *a fortiori* the military, equilibrium level.

The age and sex composition of the population is now, with local aberrations, almost regular. The regular age and sex composition is by no means the best suited to certain purposes; but social policy in this country (and indeed throughout the West) has never seriously contemplated trying to modify it for ulterior purposes.

The ethnic composition of the population (20·89 per cent. European, 79·11 per cent. non-European) is very unusual, and held by Carr-Saunders and others to be disadvantageous. Through control of migration, and perhaps in other ways, occasional attempts have been made to modify this composition is some slight degree; but no proposal to shift the balance seriously has ever affected policy.

Qualities can be assessed only in terms of purposes. But a negative approach, in terms not of positive qualities but of defects, will carry us well into the realm of practical issues. I single out the following examples:

1. *General sub-health*, in large measure reflecting a state of malnutrition.

After what has been said this morning, it would be otiose to multiply evidence of the prevalence of malnutrition in the Union.

2. *Physical Disease*, particularly Tuberculosis.

Tuberculosis has proved one of our most assimilable immigrants. Well within living memory, the disease was still a rare one in the Union, and in 1936-37 the notifications totalled 10,551. During the past twenty years, while the British tuberculosis death-rate has been halved, that for the Union has apparently remained stationary.

3. *Physical Defect.*

The number of deaf, dumb, and blind persons and epileptics in the Union is unknown; but voluntary returns revealed that at the time of the 1936 census there were, in the European population of 2,003,857, at least 5,259 persons with one or more of these afflictions. The number of cripples and cardiopaths in the Union has not been computed.

4. *Mental Defect and Disorder.*

The number of mentally disordered and defective persons in the Union is unknown; but official returns show that 13,502 such persons, amounting to 0·34 per cent. of the European population, 0·08 per cent. of the Native population, and 0·18 per cent. of the rest of the population, were in institutions and single care in 1936.

5. *Defects of Character and Temperament.*

In any group of persons there will be found defects of character and temperament, few of them absolute and none of them measurable. Among those pertaining to the Union's resources which have been furnished with some measure of statistical commentary in official publications are the following:

(i) Criminality.

(ii) Juvenile Delinquency.

(iii) Alcoholism.

(iv) Drug Addiction.

Mention should perhaps also be made, though with considerable reservations, of

(v) Certain less sharply-defined socio-psychological traits attributed to various sections of the population by official and semi-official commissions. Thus, the Cape Coloured Commission, after commending certain qualities of many Cape Coloured persons, attributes amoral attitudes and weaknesses of character to others. Again, to curtail a list which might be greatly extended, Finding 53 of the Carnegie Commission states that "a part of the poor white class is characterised by one or more of such qualities as improvidence and irresponsibility, untruthfulness and lack of a sense of duty, a feeling of inferiority and lack of self-respect, ignorance and credulity, a lack of industry and ambition, and unsettledness of mode of life." (" One or more " is not overwhelmingly damning; on such a count, who would 'scape whipping?) One observation should be added. The association of these almost legendary defects with poverty has always been a central theme in the folklore of sociology. It is only in comparatively recent times that we have come to believe that the defects may be consequents of the poverty and not wholly its cause.

The concept of social work has never been standardised. For the time being I define social work in the Union as consisting typically of the following activities:

I—*Activities of the Central, Provincial and Local Governments:*

1. The provision of poor relief.
2. The payment of old age pensions.
3. The payment of grants and pensions to the physically unfit and physically handicapped.
4. The provision of milk for school-children.
5. The subsidising of the sale of butter to certain classes of poor persons.
6. The subsidisation of "sub-economic" housing.
7. The subsidisation of hostels for low-paid wage-earners.
8. The subsidisation of charitable institutions.
9. Institutional provision for children needing care.
10. Institutional provision for the sick and physically handicapped.
11. Institutional provision for the mentally defective and disordered.
12. Institutional provision for the destitute.
13. Free educational service.
14. Free medical service.
15. A wide variety of guidance and advisory services.

II—*Activities of the Churches:*

1. The provision of poor relief.
2. A wide variety of institutional provision.
3. Advisory and guidance services.

III—*Activities of Approximately 1,000 Social Welfare Organisations.*

1. The provision of poor relief.
2. The administration of certain government provision.
3. A wide variety of provision in orphanages, homes for the aged, creches, homes for the sick, shelters, almshouses, social farms, and other institutions.
4. Administration of clubs and settlements.
5. Advisory and guidance services.

Social-work activities have four kinds of effect on human resources:

1. *Maintenance.*

The provision of the necessaries of existence and the relief of conditions threatening death—the Samaritan's oil and wine and two pence—were the earliest examples of social work as we know it to-day. They are the most obvious safeguards of human resources, but not necessarily the most effective. As emergency measures, they constitute that kind of prevention which is demonstrably not better than cure. Maintenance of human

resources is the principal effect of the following branches of social work in the Union:

(i) Provincial and local poor relief.

(ii) Semi-public and private charity.

(iii.) The payment of grants and pensions to the unfit and handicapped.

2. *Stimulus.*

A paradox of poor relief that has become a commonplace of social work is that relief aiming only at maintenance may lead to deterioration. This has been urged in some detail by the Kimberley Conference and the Carnegie Commission. It is clear that " deterrence " is a counsel of needless despair. If the effect of social work is sometimes to reduce the incentive to work, and so the effectiveness of existing human resources, social work may also, by increasing the prospective profitability of self-maintenance, by advice, education, propaganda, example, and after-care, or by making assistance dependent upon the fulfilment of suitable conditions, strengthen the effectiveness of the human resources it succours. In such ways, almost any existing kind of social assistance may be so administered as to have a stimulative rather than a narcotic effect. Particularly is this true of social insurance, with which the Union is at present ill-equipped. It is probably also true, on balance, of old age pensions and of most services aiming at what I shall call improvement.

3. *Improvement.*

Improvement—habilitation rather than the more limited aim of rehabilitation—is the conscious goal of a growing proportion of the Union's social work. As such it is tending to take the place of penal treatment on the one hand (*vide* the Children's Act of 1937) and of mere maintenance relief on the other.

The improvement of human resources by social work may be achieved in two ways:

(i) Directly; as when the provision of milk to children combats malnutrition and tuberculosis, or when the provision of free medical services leads to a reduction in the incidence of venereal disease.

(ii) Indirectly; as when the relaxation of economic pressure through social assistance helps to avert the development of mental disorder or the provision of free special education enables indigent blind persons to become capable of paid work.

4. *Replacement.*

Whether or not an increase in population is desired—and I have suggested that there are just as many sides to that question as there are persons in the population—the biological limits to the effectiveness of human maintenance make replacement the only alternative to extinction. As a general rule,

replacement will go on without any assistance from social work; but social work may influence both the rate of replacement and its quality.

(i) The rate of replacement by birth may be either retarded or accelerated by contraceptive advice, ante-natal guidance and care, and maternity welfare services. The quality of replacement by birth may be even more directly affected by such social work, and more generally by whatever measures affect the circumstances of family life.

(ii) The rate and quality of replacement by immigration may be affected notably by selective grants and other social assistance to prospective settlers.

In the field of population policy, where the sentimental appeal of social work is relatively weak, its opportunities for affecting the human resources of a country are probably greatest.

Social work operates through five channels:

1. The transference of money.
2. The free provision of goods.
3. The free provision of services.
4. The subsidisation of the sale of goods.
5. The subsidisation of the sale of services.

Now all of these activities have a characteristic socio-economic aspect. This was in fact the dominant aspect of an earlier social work which amounted to little more than the immediate relief of poverty. And before dismissing this view as old-fashioned, we shall do well to consider to what extent the defects we have mentioned—of physique, of health, of temperament, even of intellect—are associated with and aggravated by poverty and are subject to palliation if not remedy through the relief of poverty. There is no section of social work even to-day which does not bear this characteristic socio-economic stamp.

But modern developments in the provision of services of advice, guidance, and instruction, have added a consciously socio-psychological aspect to the socio-economic; if social work is still fundamentally concerned with poverty (and there are reasons for thinking so), it is with secondary, as well as with primary, poverty; not merely with that poverty which arises from lack of purchasing power in relation to the prices of human necessaries, but also with that poverty which arises from personal and family disorganisation and it is not susceptible to those adjustments which the possession of means would permit.

Excluding then the provision made by society for satisfaction of its *collective* requirements (order, justice, defence, as typical examples), and for satisfying the requirements of sexual, ethnic, national, occupational, or other groups on a *preferential inequalitarian* basis, I suggest that *social work* consists in social attempts to assure a general minimum standard of living to individuals and families not otherwise attaining it.

Taking this definition as our basis, and reviewing our survey of the Union's social work and human resources, what are we to judge of the effect of the one upon the other?

Eschewing criticism of technical and administrative detail, and attempting a constructive broad criticism of policy, I think we must observe that:

(1) There is a vein of ethnic discrimination which traverses social work in the Union from end to end. This vein is not constant or consistent, but its effect is cumulative, as a few examples will suggest.

(i) Free milk is available to European, Coloured and Indian school children, but not to Natives.

(ii) Subsidised butter is available to Europeans and Coloured persons, but not to Asiatics or Natives. A Coloured family now has to be poorer than a European family to qualify, although there was no such discrimination when the scheme was inaugurated.

(iii) Old age pensions and blind person's pensions are available only to Europeans and Coloured persons. Both the maximum and actual rates are lower for Coloured persons than for Europeans, and a Coloured person has to be poorer than a European to qualify.

Now in whatever ways this discrimination may be defended, it can be defended *as a method of conserving human resources* only if:

(a) The subsistence requirements of the Non-European population are less than those of the European population; or

(b) Europeans in need of social assistance are in fact committed inescapably to "conventional necessaries" in greater measure than Non-Europeans; or

(c) The Native and Asiatic population, and in a lesser degree the Coloured population, is a negligible part of our human resources and need not be maintained, still less stimulated, improved, or replaced.

Hypothesis (a) is demonstrably false, hypothesis (b) is highly dubious, and hypothesis (c) is, to say the least, temerarious.

(2) The fact that "maintenance assistance" is not rendered by the Government, but by a plenitude of independent bodies, appears to aggravate the abuses and emphasise the weaknesses of such relief.

(3) A comparative international survey reveals the paucity of provision for social insurance in the Union. There are practical difficulties in the way of such provision; all are referable to the extreme poverty of the potential contributory classes, and so add weight to my final observation.

(4) Social work has its limitations. One of these arises from its cost, which, if not only a small fraction of the national dividend, tends to discount the provident, stimulative, habilitative, and populative effects within the beneficiary groups by contrary effects within the contributory groups. It follows that social work is an effective weapon against sub-standard conditions only so long as they remain exceptional. Now in the Union they are not so much exceptional as typical. So long as this remains true, social work must necessarily fight a losing battle for the protection of the country's human resources.

We have been growing proud, during the past ten years, of the growth of our Social Services. We have less reason for satisfaction with the even more marked development of our Social Dis-Services: notably (i) our taxes and restrictions on food and other necessaries, and (ii) our restrictions upon employment and mobility. Pollok's mean almsgiver

. . with one hand put
A penny in the urn of poverty
And with the other took a shilling out.

Whether or not the poor show gratitude for such ambidexterity, they cannot be expected to flourish upon it, even though the penny were made twopence.

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(5) REGULATIVE ASPECTS; HUMAN SALVAGE THROUGH INSTITUTES WITH SPECIAL REFERENCE TO JUVENILES

BY

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Read 5 July, 1939.

It is a generally accepted axiom throughout the world to-day that the future of any country depends upon the physical and moral development of its youth, for the true greatness of a nation rests not on its material wealth and power, but rather on the character of its people. To conserve the vital resources of a nation, it is necessary to guard youth from all dangers—physical, mental, moral—to preserve its energies and potential powers, to guide its course, to permit its free natural development, to give it uninterrupted vision and to challenge it with the highest of all missions—unselfish, unstinted service to God and humanity.

Is South Africa meeting the vital needs of her youth, particularly those requiring special protection, care and guidance, that is, those who belong to the underprivileged classes, or who, because of various disabilities or lack of opportunities, have found compensation in anti-social behaviour? This question becomes most pertinent, when it is realised that to-day we have in our reformatories, certified hostels, industrial schools, certified and non-certified institutions, more than 11,000 children and young persons under the age of 21 years. In addition, there are approximately 4,000 under the supervision of probation officers, and 16,000 who have passed through our prisons during the course of a year. Why have we this young and ever-growing army of delinquents, potential social misfits and handicapped young lives? What are we doing for them in the institutions? What happpens to them after they have passed through the institutions? Are we doing anything to prevent other young lives from following them through the institutions? These are four challenging questions we cannot ignore. Let us attempt to answer them in turn.

1. Why have we so Many Children in Institutions?

According to the latest available figures (approximate), the number of pupils in the various institutions are as follows:

	European	Non-European
Reformatories	300 ...	900
Certified Hostels	250 ...	150
Industrial Schools	1,100 ...	—
Certified Institutions	5,200 ...	1,200
Non-Certified Institutions ...	2,500 ...	200
	9,350	2,450

There are, perhaps, five principal reasons for the large human flow through our institutions:

(a) *Increase in Juvenile Delinquency.*

During the past few years every large urban centre has reported significant increases in the juvenile delinquancy rate; especially is this true regarding non-European juvenile delinquency, which is assuming somewhat disquieting proportions. In Cape Town, for example, 1,662 juveniles passed through the juvenile court in 1937, whereas in 1938 the number rose to 1,725, an increase of 20 per cent.

(b) *Migration of Families and Young Persons to Urban Centres.*

Recent years have seen an unprecedented influx of Poor Whites, Natives and Coloureds into urban areas. Without going into detail, we all know that this significant phenomenon has already created political, economic, social and moral problems that have reached serious proportions in the large cities, especially Johannesburg, Cape Town, Durban and Port Elizabeth. And we must also remember the rush to the diamond fields where thousands of our people have dug their own economic and moral graves, and have become permanent liabilities to the State. It is an arresting sign of the times to note the large number of European youths between the ages of 17 and 21 who have taken to the road and have joined the professional army of hoboes.

The large continuous flow of population from rural areas to the towns has caused a feeling of restlessness, instability and uncertainty which must inevitably react on the lives of children directly affected by it. It is an interesting fact that according to Professor Willemse's survey, " The Road to the Reformatory," almost 40 per cent of the juvenile delinquents on the Rand come from families who have migrated to the city from farms and small towns.

(c) *Broken Homes.*

It is now generally accepted that broken homes constitute an important contributory factor in the causation of crime,

juvenile delinquency and general demoralisation. The great majority of our delinquents come from broken homes. In a survey on which I am still engaged in Port Elizabeth, I discover that 75 per cent. of 700 Native juvenile delinquents have no father in the home. As regards Native juvenile delinquency, the cultural factor is particularly important. In urban areas, tribal loyalty and unity give place to pronounced individualism. The detribalised urban Native is thus at a loose end, detached from the familiar background, with his tribal sanctions taken away and his controls and restraints lost. The break-up of the Native family is one of the first consequences of this cultural conflict. The inevitable result is a revolt against parental control and against the old tribal insistence on each child fulfilling certain obligations and duties both to the family and to the tribe in general. In his excellent survey, Professor Willemse reports that the broken or disintegrated home is the commonest condition in the histories of delinquents, especially girls. More than 70 per cent. of the boys and 92 per cent. of the girls come from such homes. In his 1938 report, the principal of a reformatory states that of the 95 European boys admitted during the year, only 17 came from homes not classed as broken, or where there were no serious disturbing factors.

Our institutions are fast becoming mere storage houses for the irresponsibilities of delinquent parents. It is undoubtedly true that a very important causative factor of juvenile delinquency is the lack of parental control. There are far too many parents evading their responsibilities—and we find this so even in many so-called respectable homes.

Directly and indirectly we are encouraging parents to throw their responsibilities on to other individuals, organisations or the State. By our lax attitude to delinquent parents we are lowering the standards of parenthood and are encouraging the breeding of thousands of unwanted children who are brought into the world with various handicaps and disabilities. It is true that the Children's Act 31 of 1937 gives magistrates special powers to deal with delinquent parents, but my own experience is that these provisions of the Act are not enforced as drastically as they should be. The greatest culprits are the fathers. Many of them throw all the responsibility on the wife; they think more about their pubs and clubs or business than the moral welfare of their sons and daughters. Parents must not expect to win and hold the respect, obedience and love of their children if they have not even tried to gain their children's confidence by taking a vital interest in their general welfare and setting them an example of high moral standards.

The time has arrived when in its own interests society should assume in some way more control over irresponsible parents who are not fit to be parents and whose behaviour is a contributory factor in producing delinquency in their children.

(d) *Poverty.*

There is always a close relationship between economic inadequacy and underprivileged classes. Poverty means segregation to poor residential areas; it accompanies low social status, bad housing and social disorganisation. For these reasons alone the economic factor plays an important role in influencing the conduct of the individual and social group.

Unemployment, low wages and poverty in themselves do not necessarily convert law-abiding citizens into criminals, but they certainly tend to demoralise them, and tend to undermine the tranquility and stability of home life. Unemployment definitely exposes youth to serious temptations that lead to various forms of anti-social behaviour. Thousands of our children in industrial schools, certified and non-certified institutions, are there because of destitution. And it will be found that the great majority of inmates in reformatories, prisons, and certified hostels, come from poor homes.

(e) *Belief in Institutional Treatment.*

To-day too much emphasis is being placed on the treatment of juvenile delinquency, child neglect and destitution, and too little on its prevention. Although it is necessary to deal with the individual delinquent or child in need of care, it is more important to counteract the demoralised forces which create social disorganisation and promote delinquent careers and social misfits. We first create or tolerate conditions which must inevitably breed maladjusted personalities, delinquents and potential criminals, then clamour for some immediate and drastic cure. We have thought in terms of more and better institutions, or more efficient courts and of the treatment of individuals after offences have been committed, but have made little headway in eliminating the root causes of juvenile delinquency, child neglect and destitution.

Too much faith and hope is placed in institutional treatment. We seem to forget that institutions treat only with the effects and not the causes. And let us ever remember that the best institution is but a poor substitute for a good home. There is a tendency on the part of some magistrates to commit children too readily. Private organisations and well-meaning individuals are, perhaps, the biggest sinners in this respect. They are too anxious to remove children from their homes; they tenaciously believe that institutional treatment is the only solution. It is certainly the easiest way of transferring responsibility to someone else. To a great extent the very existence of institutions is encouraging certain types of parents to shirk the responsibilities of parenthood.

There are those who believe that an increase in the number of our institutions necessarily reveals progress; for me, it is but a symptom of an increase in social disease, and a warning signal that we are not striking at the root causes of our social evils.

It is true we shall always require institutions, and it may be necessary and advisable to increase a particular type of institution, but do not let us attempt to solve our child welfare problems by depending only on institutional treatment.

2. What are we Doing with the Children in our Institutions?

To answer this question, we shall have to deal with each type of institution in turn.

Reformatories.

In our five reformatories we have to-day approximately 800 Europeans and 900 non-Europeans. Their ages vary from 8 years to 23 years, the peak age being approximately 18 years. About 60 per cent. of the European inmates have not passed Std VI. Amongst the non-Europeans, 61 per cent. are illiterate; only about 8 per cent. have reached Std. III. As compared with the previous year, 1937 revealed a significant increase in the population of the reformatories, namely, 14·4 per cent. in the European institutions, and 10·2 per cent. in the non-European institutions. The reformatories are already over-populated; especially is this so regarding the non-European reformatories To make room for the new additions, pupils in non-European reformatories must, on an average, be retained for less than one year. Here the Secretary for Education is right when he stated in his Annual Report that "it is doubtful whether the rehabilitation which is aimed at in the Children's Act can be effected in that time, and if the process of rehabilitation is to include a serious attempt at trade training, then the period of retention must be longer."

Important changes have been effected in methods and objectives of our reformatories since 1934, when they were transferred from the Department of Prisons to the Department of Education The Children's Act 31 of 1937 severed their association with the penal system. This Act has given our reformatories a new status; they are no longer penal institutions, but rather institutions where young offenders can be re-educated and reformed. But, although the Act makes this declaration and every effort has been made to remove the locks, bars, cells and prison-like discipline and atmosphere of the old reformatories, the fact remains that, in effect, as far as the inmates are concerned, the reformatory remains a penal institution. For have not their parents, school teachers, the police and even the magistrates warned them that if they continued to misbehave themselves, they would be punished and be sent to reformatories? In the popular mind, a reformatory is a prison for very bad boys and girls. The very name strikes fear in the minds of young delinquents, and carries with it a stigma ineradicable. Half the battle of reform is lost when a boy enters the institution with a deeply-rooted belief that the institution is there as a symbol of punishment and revenge. To-day, the educational programme

at our European reformatories shows no essential differences from that followed at industrial schools; they may be classed as a special type of industrial school, at which the disciplinary regime is a little more rigid than at industrial schools. To-day there is little difference, if any, in the personnel of reformatories and industrial schools. In recent years, the general standard of reformatory personnels has greatly improved. The old prison warden type of guards has given way to specially selected and trained men. Is there any reason why the name "reformatory" should still be retained? Has the time not arrived to abolish a term which conveys wrong impressions to the general public, the courts, and even to the inmates themselves?

Certified Hostels.

At present there are approximately 20 certified hostels, with a total population of more than 250 European and 150 non-European young offenders. These institutions serve as a half-way measure between the restriction of reformatory training and complete freedom in the community. To date, the hostel system has provided proof that this is, perhaps, the best method of dealing with the problem of a certain type of youthful offender—a method which should be more extensively applied throughout the country. It is interesting to note, however, that almost 19 per cent. of all the reformatory inmates have been to these hostels. It would appear to indicate that greater care should be taken in selecting the type of delinquents for these hostels.

Industrial Schools.

The eight industrial schools, which are under the control of the Union Department of Education, have a population of approximately 1,160 pupils, the great majority of whom come from poor home and social surroundings; many have been neglected and ill-treated, and, consequently, have developed social maladjustments. About 48 per cent. are committed on the grounds of indigency, or having no parent or guardian, and 43 per cent. on the grounds of truancy or uncontrollability. As a result of the new provisions in the Children's Act, the percentage of committals on the grounds of uncontrollability will rise considerably. The Act permits certain types of delinquents to be declared "children in need of care." In this event, the delinquents may be committed to industrial schools. Magistrates apparently prefer sending young offenders to industrial schools rather than to certified hostels or reformatories; the result is that there is the danger that the industrial schools will eventually become crowded with boys and girls of the pronounced delinquent type. Is it fair and advisable to allow them to come into intimate association with children who have been committed solely on the grounds of destitution or neglect or ill-treatment? It is true that even prior to the Children's Act, industrial schools have always admitted delinquents, but the fact remains that it is an unsound principle to house delinquents with bad records together with

non-delinquents. Certain experts maintain that psychologically there is little difference between a pre-delinquent and a delinquent, and, therefore, little harm can be done by grouping delinquents and non-delinquents in one institution. I personally doubt the soundness of this argument. Everything depends on the type of delinquent and type of non-delinquent who are housed in one institution. We cannot generalise.

It is unfortunate that industrial schools carry a stigma. It is generally assumed that because a boy has been to an industrial school, he must necessarily have been a delinquent. Why should children who have been committed solely on the grounds of destitution or neglect be branded with this stigma?

There should be greater classification of industrial schools to meet the needs of those with definite behaviour problems and those mentally handicapped. The starting of a special institution for the subnormal industrial school boys has been an important advance in our industrial school system.

It is not always appreciated by the general public, social workers and magistrates, that industrial schools are not merely institutions where children receive care and protection, and are taught a trade, but are also character-building institutions, where boys and girls with serious behaviour problems have to be re-educated and remoulded. In its industrial school policy, the Department of Education has been wise in recognising the necessity of proceeding along psychologically sound educational lines, and insisting that the organisation of the institutions and the methods of instruction be so adapted as to meet the needs of individual pupils.

Certified and non-Certified Institutions.

More than 9,000 European and non-European children are housed in our certified and non-certified institutions. With two exceptions, these institutions do not provide trade training, and in most cases, their academic education is provided in the ordinary public schools.

The most serious defects in our institutional system are to be found in our certified and non-certified institutions. As a general rule, with very few exceptions, these institutions are very much under-staffed; the personnel is generally of a poor standard. One is amazed to see the type of persons in some of these institutions, who are invested with the important task of moulding the character of children. They have neither the ability nor the training nor the personality to undertake such responsible work. It is true that there are excellent men and women working heroically in these institutions and under many handicaps and disabilities, but they are in the minority.

Comparatively few of these institutions can be classed as real character-building institutions. There is little, if any, real attempt at classification of inmates, while individual treatment is almost impossible, principally because of inadequate and

untrained staff. Some of these institutions have little girls from 18 months to young women of 21 years. Some of the young girls from 18 to 21, who have been released on licence and subsequently returned to the institution because of misbehaviour, are allowed to associate quite freely with the other inmates, irrespective of age. Is it sound psychologically, educationally and morally to allow girls of all ages and of all types to live in one and the same institution?

Another serious defect in these institutions is the doubtful practice of detaining a child for too long a period. For example, many children are compelled to spend twelve and more years in the same institution. Some institutions detain the children as long as they possibly can, although they have the opportunity of releasing them to their own parents or to some responsible persons. This pernicious practice has compelled the Department to request the institutions to give reasons why children who have reached a certain age, or have spent a certain period in the institution, are still being detained.

There is no doubt that some of these institutions are fulfilling a great need, and are rendering a real service to the country, but the fact remains that the great majority of them are failing to meet the real needs of the children; they are certainly serving as places of safety and protection, but are not giving that training and discipline which the majority of their inmates need. After all, it must be remembered that although the majority of the children in these institutions are there because of destitution, neglect, abandonment, or have no parent or parents, most of them are difficult or problem children, in fact, many are potential delinquents.

Prisons.

It is deplorable that despite the so-called enlightened age in which we live, we still allow more than 16,000 juveniles under the age of 21 years to pass through our prisons every year; of this number, approximately 300 are Europeans. It is argued that over 13,000 of these young offenders are Natives between the ages of 18 and 21 years, who are guilty of trivial offences, and who cannot therefore be deemed suitable cases for a reformatory sentence. If it is true that they were involved in trivial offences, is there any justification for committing them to prison, where they have to associate with adult criminals? Are we not making them accustomed to prison life at an early age? And what about the 300 European youths we allow to enter our prisons every year, there to have their young lives impregnated with the poisonous thoughts and ideas of their fellow adult prisoners? Why reform our reformatories and other institutions, when we allow an army of 16,000 youths to be bred and nourished as criminals in our prisons? Even though a youth has committed a trivial offence, we have no right to mete out mere punishment by driving him into prison; rather should we

attempt to reform and re-educate him, because very often a trivial offence is but the symptom of other deeper emotional or psychological disturbances. Other methods can, and should be adopted to save these 16,000 youths from contamination with prison atmosphere and with adult criminals.

General Comment.

The great majority of the children and young persons who pass through our various institutions are either delinquents, potential delinquents or persons with pronounced behaviour problems. They need to be re-educated to new mental attitudes, their twisted personalities have to be remoulded, and they have to be given new moral values. All this means something more than any amount of improvement or increase in the academic instructions or vocational training which they may receive in the institution. It means reshaping their behaviour patterns—it means concentrated and thoughtful attention on the particular problem and difficulties of each individual. Our institutions should therefore give more and more attention to individualisation of treatment. The individual boy or girl, not the institution or the group, should hold the centre of the stage. Our reformatories and industrial schools are making a brave effort to achieve this end, but their efforts will always be seriously handicapped as long as we continue with the present unsatisfactory method of classification and committals.

We should provide for a more graded system of institution based on differing psychological, emotional and mental needs requiring different methods of treatment. For example, the subnormal delinquent should be removed from the ordinary reformatories and be given special attention as is now being done with the subnormal boys in industrial schools. Special provision should also be made for delinquents who are suffering from neuropathic constitutional defects which bring them into the class of psychopaths.

Children and young persons are committed to various institutions direct from the courts, without due and proper consideration of their particular needs. Because a boy has a number of convictions or has committed a serious offence, the majority of magistrates believe that he must necessarily be committed to a reformatory or certified hostel. In fact, unless the boy can be declared a " child in need of care," the magistrate cannot commit him to any other institution. The result is that many boys and girls are committed to these institutions who are definitely not suitable candidates for such institutions. Again, magistrates often commit children to industrial schools who are unable to profit vocationally, or who are definitely subnormal. Very few magistrates know anything about the training and treatment given in the various institutions. In the great majority of cases, they are not in the position to state what type of institution is the best suited for a particular child or young

person. Even the probation officer, who knows all the circumstances of the case, is not always able to say to what type of institution the child should be committed. A special institution or "observation centre" should be established, to which doubtful and problem cases should be sent for preliminary specialist study and observation before final disposal is decided upon. Such a centre would avoid many transfers from institution to institution, and would, no doubt, also reduce the number of absconders. Many pupils fail to respond favourably to institutional treatment simply because they have been placed in the wrong type of institution and have thus been unable to make the necessary adjustment.

3. WHAT IS HAPPENING TO EX-PUPILS OF OUR INSTITUTIONS?

It is estimated that more than 2,000 pupils are released every year from our various institutions. What becomes of them? Do they eventually become law-abiding citizens, or do they drift back to poverty, anti-social behaviour and general demoralisation? It is believed and hoped that the great majority of them have made good. But it is possible that we are living in a fool's paradise. No attempt has been made by any Government Department or any institution to assess scientifically the real value of the work done in terms of the success or failure of the ex-pupils in after life. It is a deplorable state of affairs that we go on quite happily pursuing the old paths or branching out into new ones, without troubling to test the results of our old or new methods. How dare we formulate new policies when we have no data to indicate whether the old policies have been successful or not? In our reformatories, for example, we have removed the locks, gates, fences and other evidence of the old prison-like régime. We have introduced a new educational system, new methods of training, and have, in short, created a new atmosphere in our reformatories. In theory these fundamental changes appear sound, plausible and commendable. The inmates appear happier and more contented. But are they being permanently reformed? Is their apparent happiness a sign of permanent changes in their make-up or are they just having a better time than their predecessors? If we are searching for truth we are entitled to ask these pertinent questions. The great changes in our reformatory system may be very sound, but to date we cannot prove it by facts nor can we even compare it with the results under the old system. We have also affected important changes in our industrial schools. Again we ask, are we certain we are on the right road?

It is unfortunate that because of the increase in committals certain institutions are compelled to release many of their pupils prematurely in order to make room for the new arrivals. If this practice is allowed to develop, there is the grave possibility that the whole purpose in committing children to institutions will be defeated, and the institutions concerned will, in effect,

become mere places of detention. We cannot expect institutions to fulfil their proper functions if pupils are detained for comparatively short periods.

It is erroneously believed that because a young person has been in an institution for some years, he must necessarily be so equipped physically, mentally, vocationally, and morally, that he is perfectly fit to face life's battles. It is not always realised that no matter how good an institution may be, its atmosphere and environment will always be unnatural. The pupil's freedom and independence must necessarily be limited; they become mere parts of a machine, which they automatically obey. When released, they are thrown into a world of freedom and complete independence; the world is unsympathetic, impatient and indifferent to their problems. It is during this difficult period following their return to community life that ex-pupils have to look to probation officers for counsel and guidance. To-day, more than 4,000 young persons are under the direct and personal supervision of our probation officers. It is their onerous task to assist these young persons to adjust themselves to their new life of freedom, independence and responsibility—a task made all the more difficult when many of these released pupils have to return to unsatisfactory home conditions, and have to roam the streets, begging for work. How pathetic to see many of our institutionalised boys and girls drifting into a life of general demoralisation just because of the very circumstances which sent them to the institutions. It is here where the good work of some of our institutions is undone. It is of prime importance that the released pupils shall be provided with suitable homes and jobs sufficiently lucrative to keep them from want and temptation.

It is to be regretted that certain employers of labour do not give ex-pupils full credit for the training they received in institutions; for example, boys who have had 2½ years' training in their particular trades and are subsequently apprenticed, are generally credited with only six months' training. In fact, as regards certain trades, some employers will have nothing to do with boys who have had their training in institutions. If our boys and girls are to be rehabilitated and given the opportunity to make good, employers of labour and the community as a whole must work loyally and sympathetically with our institutions, which are rendering vital services to our youth. It is true that a large percentage of ex-pupils are unable to make primary use of such vocational training as had been given to them in the institution. One reason is that the training planned for them is not always related to the situations in which they would inevitably find themselves on release. The problems of the individual boy are not always studied thoroughly, and assignment to training is determined, to a considerable extent, by the number of vacancies in a particular branch of training. In any sound vocational-training programme, the training must

be merged with vocational guidance. This is one of the most challenging aspects of institutional work. There is need for a thorough investigation of the whole vocational training field in connection with institutional treatment.

4. What are we doing to Prevent Young Lives from Becoming Institutionalised?

As already stated, there are many who believe that the only solution to the various problems involving children and young persons lies in institutional treatment. We are gradually reaching the stage when it is taken for granted that no child is sufficiently equipped to face adulthood unless he has been through some institution. Even many intelligent and responsible parents are all too anxious to send their children to boarding schools or other institutions. As soon as their children give them the least amount of difficulty, many parents rush them off to institutions; in short, the institution is gradually taking the place of the home. There is far too much emphasis on institutional treatment and too little on family rehabilitation and on the reconstruction of home life. By over-emphasising institutional treatment, we are definitely undermining the solidarity of our homes and weakening the ties and loyalties of family life. We should concentrate more on rebuilding and remoulding the homes of children who need special care and protection. It is true that it is always necessary to deal with the individual child, but it is also vitally necessary to deal with the essential needs of the family. After all, the child is but the unit of a group. To strengthen the unit, we must strengthen the group and *vice versa*. Why commit a child to an institution, and at the same time allow its home to deteriorate and its parents to produce more social misfits and candidates for institutions? How pathetic that many children, after spending years in institutions, have to return to their old deplorable home conditions!

The Department of Social Welfare is battling heroically to stem the growing tide of destitution, child neglect and juvenile delinquency; for example, this year it will pay out close on one-third million pounds in the form of maintenance grants to necessitous children who are thus able to be kept at home. By extending probation services, the Department is seriously attempting to undertake constructive preventive work, but, unfortunately, all the probation offices are very much understaffed, and are unable to cope adequately with their increasing work and responsibilities. It is not too much to say that probation officers are, or should be, the most important workers in our whole programme of social rehabilitation. To-day they serve as links between the Department of Social Welfare and private social welfare organisations; they are the eyes and ears of the Department, they come into vital contact with all our social problems; they are not only social welfare workers, but also moral reformers. To-day more than 4,000 young persons

are under their supervision and subject to their guidance. It must be clear to all that every effort should be made to extend probation services so that the team of probation officers may extend and develop their invaluable preventive work. But probation officers can do little, and the Department of Social Welfare less, without the spontaneous and whole-hearted support of public bodies, private social agencies and private individuals.

It is the popular cry that the Central Government must take responsibility for all our social problems. It is true that the Government has its responsibilities, so have the provincial authorities, but it is not always realised that local committees have their responsibilities too.

The problem of juvenile delinquency, child neglect, broken homes and delinquent parents, cannot be removed with ease; they are indications of weaknesses and maladjustments in the whole social organisation. Concentration of community, responsibility and fundamental co-ordination and integration of effort are lacking. Is it not time that there should be greater centralisation, greater concentration of effort and co-operation on the part of societies and organisations engaged in social welfare work? The public must be brought to the realisation and acceptance of its responsibilities in the prevention of juvenile delinquency, destitution and child neglect; the public must accept a constructive community programme to accomplish these ends. We must organise all the community resources interested in the child, and weld them with enforcement agencies into a harmonious working unit to the end that all children, whether privileged or under-privileged, delinquent or non-delinquent, may be adequately protected and cared for. Reduction of juvenile delinquency and child welfare problems depends upon the awakening of the community consciousness to the point where the community faces and accepts its responsibilities. The whole entire social group must co-operate in the attempt to deal with the basic needs of the child, especially the under-privileged child And what are these basic needs? Surely they are these: an adequate education, sound health, wholesome recreation and wholesome surroundings.

It is to be regretted that we are not yet making full use of our mental science in dealing with behaviour problems in children and the mentally retarded. In this respect it is gratifying to note that the Cape Education Department has started special classes in the schools for retarded children. It is submitted that if we paid more attention to the early symptoms of deviated behaviour in children, we would save many of them from becoming mere institutional beings. The causative factors leading to delinquency and criminal careers are found in early youth. To strike at the roots of crime and delinquency, we must concentrate on the needs and problems of the child; mental hygiene clinics and child guidance clinics should, therefore, be fostered wherever possible.

The lack of adequate recreational facilities and the ill-use of leisure time opportunities are important factors in the causation of crime, delinquency and the general demoralisation of youth. It is to be deplored that thousands of our children are allowed to roam the streets simply because they have no playing fields and have no opportunity of joining any character-building organisation. The spread of the boys' club movement is, therefore, highly to be commended, especially the Government's efforts in assisting clubs financially; these clubs are fulfilling a real need among the under-privileged boys.

To save our youth from becoming State liabilities, we must give them new mental attitudes, new interests, new habits and new moral values. Employment, adequate wages, improved environment, will not necessarily give delinquents new moral standards. After all, apart from the economic and social factors, juvenile delinquency, child neglect and destitution are moral problems. Many do not like the introduction of moral issues in the discussion of social problems. But why are we so afraid to mention the question of personal individual morality when we know in our own hearts that at the foundation of all our problems, political, economic, social, lie the personal individual moral issues? Are we to continue to live in a world of make-believe and hypocrisy? It is to be deplored that to-day so many adults who should know better are but poor and uninspiring examples to our youth. The greatest hope for the prevention of juvenile delinquency lies in the good examples set to children by adults. It is just here where our social problems are direct challenges to us who claim to be intelligent, respectable, responsible citizens. Are we prepared to accept that challenge? If so, there is hope for our boys and girls, especially those who pass through our various institutions.

Human salvage through our institutions will become human wastage, unless probation officers, social workers and we private citizens can give our youth new inspiration, new faith in themselves, new hope in humanity, a new vision of their ultimate destiny, a new sense of responsibility, and, greatest of all, a new love for God and their fellow-beings. It is to achieve these ends that we should strive to give youth its vital needs, to protect it and guide it, thereby conserving the human resources of our country.

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(6)—PSYCHOLOGICAL ASPECTS: WITH SPECIAL REFERENCE TO CHILD GUIDANCE, VOCATIONAL GUIDANCE AND EDUCATION

BY

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Read 5 July, 1939.

As the science which concerns itself with the conscious and unconscious life of man, with aptitudes and abilities, with the activities and behaviour of man, psychology has in the course of its development been actively interested in the conservation of human resources. Vocational tests, vocational guidance, the analysis of activities required for the performance of tasks so that unnecessary movements may be eliminated and time and energy be saved, fatigue studies, investigation into the causes of crime: these are a few of the directions in which psychological study has been applied to industry, education, law, social service and other forms of human endeavour. The specific types of investigation and the application of the results for the purpose of conserving human resources are of course to some extent determined by the particular needs of the country and the time. So for example, most of the psychological work in industry had its origin in America and other large industrial countries.

In South Africa, we too, have our specific problems. From time to time attempts are made to deal on general lines with those problems which have become troublesome. So during the recent session of Parliament some members, perturbed at the low standard of living of many Europeans and at the competition of the native and coloured with the European in the market for unskilled labour, suggested that certain vocations should be reserved for Europeans (the implication, it seemed to me, being that the hardest and worst paid work was to be reserved for those who had not the good fortune to be born with a white skin.) At the same time the Cape Provincial Council, perturbed at the large number of boys and girls, particularly in the country districts who failed to make progress at school beyond the standard VI stage, agreed to set up a Commission of Enquiry to investigate the possibility of giving these children some form of technical or vocational training. Another problem, another Commission. Far be it from me to criticise Commissions. There is indeed nothing to be said against them, if they base their findings on facts rather than on opinions. The report of the Poor White Commission is an example of what valuable work a Commission can do, but this was one of the Commissions which

based its findings on facts. Scientific investigation into the problems that worry our legislatures—and ourselves—in order to find and interpret the facts—as is the case with problems in other fields, would, it seems to me, provide the material for satisfactory solutions. To enumerate all the problems awaiting investigation is, of course, impossible in a paper like this, and it would be presumptious of me to suggest that I know them all. I don't. But it is my aim to mention briefly some of these problems which might profitably be investigated from a psychological point of view and with the techniques developed by psychological research.

There is the question of school education. It has been and is being taken for granted that man is of more use to himself and to the community in the measure that he is educated to take his place in it, to use his abilities with ease and efficiency. The better the education, other things being equal, the more useful and the happier the man. Consequently there has been a general boosting of schooling: free compulsory schooling for all Europeans, a minimum school leaving age, continual "hues and cries" to "keep the children at school" and frequently it has been seriously advocated by responsible bodies and individuals, amid applause, that unemployment would end if the minimum school leaving standard were to be raised to standard VIII—the J.C. The argument runs more or less as follows: Pupils who have passed the J.C. find work more readily than the standard VI-ers. Hence solve the unemployment problem by making all your pupils pass the J.C. or Matriculation—forgetting of course that the reason why they find work more readily is because there are fewer of them available for the work. But we find that hundreds of children leave our schools every year without even having a standard VI certificate, and thousands more immediately after having completed the primary school course. In the schools of the Cape Province I found last year that of 7,500 pupils who had left school 1,100 (about 15 per cent.) had not reached standard VI, and 3,150 (i.e. 42 per cent.) had just passed it. I happen to have the data about the Cape system, but there is no reason to believe that the position is any different in the other Provinces. And no matter how High School syllabuses are watered down and easier courses introduced in the place of the more difficult ones we shall always find this condition of affairs, because there is the matter of intelligence: the problem of ability to profit by High School study.

As the result of psychological research it has become possible to test and determine the standard of intelligence of pupils. Now I know that intelligence tests have often been criticised as being misleading and unreliable. They have been criticised as testing memory, general knowledge, speed of reaction and so on—everything except intelligence. Now this criticism is unfair and would disappear if the critics understood what intelligence tests are intended to do. Intelligence can not be tested directly. We have

no means of measuring it directly. Intelligence does however express itself in various activities, especially in thinking activities: activities in which eductions and deductions are made. These activities might be called *the products* of intelligence, and these products are certainly measurable. Intelligence tests aim at measuring the products of intelligence, and from these measurements deducing the amount of intelligence. The tests may not be perfect; they may measure other things besides the products of intelligence; they may, for instance, measure knowledge which has been acquired in different ways and to different degrees by different people; and in so far as they do this the tests are not good instruments for measuring intelligence. But in spite of whatever shortcomings they may suffer in this way, intelligence tests are the best instruments we have to-day for measuring intelligence.

By the application and use of these tests it was found that intelligence is normally distributed, and that the distribution can be graphically represented by the normal probability curve. This means roughly that taking say 100 as the average intelligence quotient most people are grouped round about the 100, and there are as many above it as below: as many and as few having 120, 130 etc. for an I.Q. as there are below 80, and below 70 respectively. In his investigation "Education and the Poor White" Dr. E. G. Malherbe found, tentatively, that 100 I.Q.—that is the average I. Q.—was the minimum standard of intelligence required in order to be able to pass our matriculation examination. That means that however long the children remain at school at least half cannot possibly matriculate. Actually less than 10 per cent. do. Over 40,000 pupils have not the intelligence to enjoy any benefit from any form of High School training: that is to say they cannot progress beyond standard VI—if they get there at all. Now it seems to me a waste of human resources to keep pupils at school beyond the point at which they are able to gain any benefit from it for lack of the requisite intelligence. On the other hand we know that pupils who do possess the necessary intelligence often have to leave school for lack of the requisite funds before completing the matriculation course. It seems to me that much human energy can be conserved if pupils who gain nothing from our ordinary system of schooling should be encouraged and if necessary compelled to leave school—or at least that they should not stay there at the expense of the state. The money so saved could be applied to the education of those who have the ability but not the money. I am not, of course, suggesting that those who can obtain no benefit from ordinary schooling should be withdrawn from the schools and thrown upon their own resources. There may be special types of work for which they are fitted intellectually and for which they can be trained. This would have to be the subject of investigation: one of the problems before us. I am returning to this matter at a later stage.

The suggestion I am putting forward in regard to the intellectually unfit pupils is not intended as a plan to serve as a panacea for conserving human resources. It is merely intended as an indication of one direction in which investigation might usefully be made.

During the last few years we have begun to appreciate that mentally retarded pupils do not gain much, and in fact may suffer injury, from being kept in the ordinary school classes, and special classes have been organised in the Cape system, and elsewhere for them. But it has also been realised that bright pupils, pupils of superior intelligence, often waste time and energy, become bored and tired of school life, by being forced to remain in the company of average or dull pupils and to progress at their rate. Popular education tends to raise the school standard for some pupils and to lower the standard for others, especially for those of greater ability. No facilities have been organised for the bright child. It seems to me that a useful investigation might be made in the direction of instituting special classes for the intellectually brighter children, of whom there are as many as there are mentally retarded ones. It is a tragic mistake to assume that the able scholar gets there all the same, whatever his opportunities at school. Some are fortunate and get there in spite of their handicaps. But to anyone who has worked with such pupils it is obvious that among them "full many a flower is born to blush unseen, and waste its sweetness on the desert air."

At present the retarded pupils are being taught by special methods and are given special tasks suitable for their abilities. But there is no information available as to whether the skills and techniques they have acquired will help these children to earn a living: whether they will be enabled as the result of the special training to put their abilities to the best possible use. In fact this also applies to our High Schools and Secondary Schools. The syllabuses contain certain subjects which for the greater part will never be of use to the pupils in their future lives. For example: because Latin was the universal language of the cultured man centuries ago it was made a study in the schools; but though this universally cultured language has for many a long year been superseded by the various European languages our children at school still learn Latin. Whether they will need it or not our children take mathematics and modern foreign languages. The contention that these studies assist in training a mythical kind of faculty for remembering, reasoning etc. has been thoroughly disproved by scientific investigation. I do not wish to be misunderstood. I do not suggest that these subjects should be dropped. In fact for some pupils they should not be dropped. If for a study of law Latin is required, or mathematics for engineering, etc., then for pupils who intend to adopt these vocations they should be retained. The point I desire to make and stress is that investigation should be made into what

we wish our pupils to know as men and women and what skills we wish them to acquire, in order to determine how that knowledge and those skills can most advantageously be acquired at school. Most country boys, for example, who leave school at standard VI go farming, and the right training would seem to be to prepare them for that work. Research and still more research.

And this matter of ability and skills brings me to another important problem in the conservation of human energy, namely in connection with our large non-European population. In many of the non-European schools the European syllabus has been introduced holus-bolus. It may be the aim of the educational authorities responsible for this system to cause this population to adapt itself to European economic conditions in order to compete on the European labour market. But at the same time that the European education is being given them, fear of their competition finds expression in the form of laws enacted to prevent them from competing on that market. They are therefore as a population being prepared for labour conditions in which they are not permitted to compete and live.

And there is an even more vital problem in this connection. Is the average Native able to absorb this sort of education? Has he the innate ability to absorb it? When we look at the Native leaders there seems to be no doubt that at any rate the best of them can, and do, profit by the system. But what about the large masses? In a recent investigation on "The learning ability of the South African Native" I found that the average Native was very much inferior to the average European in acquiring skills in which a certain amount of thinking and solving of difficulties was involved. In a subsequent, as yet unpublished, research, it appeared that the native having once acquired a skill did not forget as quickly as did the European. If further investigations were carried out to determine in what respects the Native is inferior to the European, in what directions he has abilities equal or superior to the European, the results obtained would point the way to types of work for which he would be specially suited, and consequently to the sort of education which would suit him best. If certain types of work were reserved for Europeans and others for non-Europeans on the basis of this kind of investigation, conservation of human resources would be effected to the advantage of both the European and the non-European.

But there is still another aspect of the problem of the conservation of human resources that needs investigation. In an earlier part of this paper I referred to an investigation in regard to the vocations followed by pupils after leaving school. I found that of 7,500 pupils 2,400 i.e. 32 per cent. had no kind of work at all twelve months after leaving school. Shown in standards at the time of leaving school the following are the figures: Standard X, 10 per cent.; Standard IX, 25 per cent.;

Standard VIII, 20 per cent.; Standard VII, 40 per cent.; Standard VI, 36 per cent.; below Standard VI, 33 per cent,. If we consider the boys only, the percentage of those unemployed is slightly smaller. They are: Standard X, 7 per cent.; Standard IX, 15 per cent.; Standard VIII, 12 per cent.; Standard VII, 25 per cent.; Standard VI, 18 per cent.; below Standard VI, 20 per cent.

Furthermore a large percentage of the school leavers who had procured work was in possession of school qualifications higher than those demanded by the work upon which they had entered. This means that they had qualifications and possibly abilities greater than that needed for the work. They were not necessarily doing the work suited for their abilities, but they had been fortunate enough to obtain some form of employment. Incidentally we do know that a man who has too little ability for a job cannot possibly adapt himself to his work, produce his best and be happy in it. It would seem obvious that positions for which much ability is required should be closed to applicants who do not possess the requisite ability. This is not the case at present. There are for example numbers of students at the Universities who should never be there. They scrape through matric. and waste time and energy training for professions—and some of them succeed in entering professions for which they have neither the intelligence nor the special ability. They are misfits in their profession, subject to all the unhappiness and ills that lay wait for their kind. What we frequently do not realise is that just as a man can have too little intelligence for a job so so he may have too much. A highly intelligent person cannot possibly be happy and produce his best, for example in a job in a factory doing some routine work at a machine. This is essentially the work of the duller, the less intelligent person. In England one of the inspectors of the L.C.C. schools recently told of how some employers had been persuaded to take mentally retarded pupils into their service for certain types of routine factory work, the point being that the routine nature of the activities was best suited for that sort of child and that he did it best. The result was that the employers concerned became convinced of the value of this type of worker for this type of labour. A visit to a place such as the Alexandra Institute at Cape Town, would afford an illustration in an extreme form of the way in which backward—in this case feeble-minded—children can do good work if they can do the same task over and over again. And what is more, they are happy doing it. Research in this direction is very necessary, and could and should indeed be directed to the various kinds of work available, the type of activities performed in the course of the work, the human material available and best fitted for the work. Such a survey is called for not only in regard to retarded pupils but generally.

One of the least known but most important aspects of the problem of conservation of human resources is the problem of

avenues of available employment. We read from reports of labour bureaus that there is no unemployment and yet we know that relief works are being maintained by the state. Difficulty is very often experienced in obtaining applicants for available positions. Regular Union-wide surveys of avenues of employment would seem to be indicated, the results to be made public by means of the press, films, radio and other sources available for publicity.

These then are a few of the problems which can and should be investigated from the psychological, vocational and educational points of view. It will be obvious that I have only touched the fringe of the whole position, but that was all I needed to do to make my point that general discussion uninformed as to essential facts could not bring about any lasting contribution to the problem of the conservation of human resource, and that these essential facts could only be obtained by investigation.

To some degree investigations are being proceeded with at the present moment. The Universities are doing something, and individuals too, encouraged by that excellent state body *The South African Council for Educational and Social Research.* But research workers in Universities and elsewhere labour under disadvantages and difficulties in regard to obtaining information and for lack of time and funds. The work is important enough to be undertaken by the State as is the case in agricultural and other fields. That excellent department *The Bureau of Educational and Social Research* could for instance be enlarged in order to study and investigate the problems I have mentioned and the many others waiting for solution to make life more useful and happier for our citizens. But above all I have tried to make the plea that general discussion by Parliament, Provincial Councils and Commissions (or by us) may have their uses but can lead to no solutions unless they are informed by the products of research, research and still more research.

South African Journal of Science, *Vol. XXXVI, pp. 552-555, December, 1939.*

(7)—WHAT OF THE FUTURE?

BY

Theo. Harms, Esq.,
Farmer, Estcourt.

Read 5 July, 1939.

The problem of the white man's destiny in South Africa has exercised the minds of many. Somehow there is a feeling that all is not well. Though the vast majority of people resolutely assert that South Africa is a white man's country, there are others with a more pessimistic turn of mind to whom it is only a question of time before the European will go under in a sea of colour.

To arrive at a conclusion instead of expressing a belief, it will be necessary to examine how the European fits into the South African equilibrium.

Equilibrium means the various forms of life living together in such a manner that each finds its rightful place in relation to all the others. If this is investigated more closely, and nature and the various forces of nature are observed at work, it will be seen that there is evolution bringing forth the various forms of life in unending variations. This is assisted by such forces as "self preservation" and "preservation of the species" which give each newly evolved life a chance to survive; but there must be some other force to bring order into this vast chaos of living things. We will presume that such a force exists and call it "Harmony" for want of a better name. It is evident to the observer of nature that a fitting place must be found for the evolved creature, that some control over its behaviour is necessary and a check held on the urge for reproduction. The living form either fits into the whole or has to be toned down to find its niche or it will be ruthlessly destroyed. This is "Harmony" at work; it will readily be acknowledged that it plays a very important part in bringing about the equilibrium.

In further pursuing the subject, another interesting factor reveals itself. "Harmony" always sets up the equilibrium at the highest level of production of living forms as regards varieties, numbers, quantity and quality (including the human mind) possible under the conditions prevailing. This fact is of

the greatest importance and enables us better to understand the white man's position in South African life.

This country three hundred years ago was a virgin land, unspoiled in its rolling veld teeming with game and representing the natural South African equilibrium. The plant life, the animal life, and the aborigine with his own typical mind were the best that South Africa could produce.

Into this stepped the European.

He also is the product of his own equilibrium and he is of a higher order than the man of the South African equilibrium. So are his requirements of a higher standard. Wherever he goes he demands the environment to which he is accustomed; where he does not get it, he sets about getting it. This is what has happened in South Africa. The equilibrium was actually raised to suit the demands of the invaders. In the beginning this was done by the importation of commodities. The white man then looked round to see whether the country could satisfy his wants. It could not. Cultivated plants had to be introduced from Europe, and stretches of African vegetation were destroyed to make way for the European product. The animal world was treated even more ruthlessly. As the game was not productive enough, it had to give way to the European domesticated animal.

How did the South African equilibrium react?

It is often said that nowhere in the world are there more pests and diseases than the South African farmer has to combat. Lungsickness, rinderpest and East Coast fever swept in great waves over the country and nearly decimated the imported stock. Insect pests, fungi and bacterial diseases are the bane of the agriculturist. Does it not appear that "Harmony," unable to fit the imported animals and plants into the South African equilibrium, is doing its best to destroy them?

Man has, however, been able to combat disease fairly successfully by preventive measures, by isolating animals and confining them on restricted areas or farms and by waging continual war against the eternal microbe, but reaction had already set in. Animals protected in such a manner have increased rapidly. This fact and the restricted areas in which they are grazed are responsible for the destruction of the vegetation in ever increasing proportions. Furthermore, the destruction of plant life to make room for the imported product has been the cause of much soil erosion and loss of fertility in our soils. The ultimate outcome of such wholesale destruction must be desert—caused by the white man!

An interesting feature in this country is to be found amongst native cattle. Many are the offspring of imported animals but

how they have changed! They resemble game more than imported cattle, are more disease resistent but less productive. They have become part of the South African equilibrium proper, having been toned down to fit into the order of things.

And the white man! Has he been able to withstand the influences of his new environment?

There is the problem of the "poor white" in this country. He seems to be a purely South African product. It is a significant fact that the "poor white" consists chiefly of those people who have longest been exposed to the South African environment, with the result that a large number of them are deteriorating fast. A loss of energy and will power is most noticeable, as well as a loss of race consciousness.

Here it again appears that "Harmony" is busy moulding man and beast ultimately to fit them into the South African equilibrium.

If this country were isolated from all the world, it is not difficult to visualise the result. Cut off from European civilisation, culture, science and art, with no import or export of commodities, the white man would be in an impossible position. Despite our institutions, in spite of our gold, most men would soon become so impoverished in body and mind that they would follow the poor white. What an easy task for Harmony to level them all down to the standard required to fit into the equilibrium!

From this discussion it would appear that the white man has little chance to survive and that he is condemned to extinction in South Africa, but so far only one side of the question has been considered.

On the other hand, it can be pointed out that the white man has lived for several centuries and is still going strong; that if deterioration has set in it has affected only a portion of the people.

It may be argued that the progress has been made that our civilisation is on the same level as that of Europe, and that South Africa has produced some wonderful minds. The production of food and other agricultural and pastoral products has progressed to far more than can be consumed in this country.

Some of these arguments are quite sound, and, although we may not quite subscribe to them, they show us a way out of the difficulty. South Africa can produce food in abundance, but the cost is far too high under present methods of production. South Africa can produce great minds, but we must remember that a close contact with Europe has had its effect in their development. So we will draw our conclusion.

If the white man remains in South Africa, the equilibrium will have to be raised considerably and be permanent. The far future must be considered to a yet unheard-of degree. Perhaps quantity will have to be sacrificed for better quality to balance matters correctly. We shall have to manage more carefully the natural resources of our country and be careful not to destroy anything which cannot be replaced. A more active intercourse with Europe to and from South Africa is indicated. A continuous flow of fresh vigour and mind such as Europe only can produce is essential if we are to avoid deterioration and maintain the high standard of living necessary to our well-being.

To check deterioration of our people, let us take advantage of such areas which most closely resemble the European climate and reserve them exclusively for the settlement of the white man. The invigorating winter of the South African highveld is the breath of life to him.

It remains to be seen whether we as a nation will be able to grasp the seriousness of the position, and, if we do, whether we can produce sufficient energy to tackle these problems on the scale they demand in order to save the country and the future of the white man in South Africa, and whether we can realise that even partial isolation means retrogression.

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(8) HUMAN ECOLOGY: WITH SPECIAL REFERENCE TO MAN IN RELATION TO HIS ENVIRONMENT AND THE DISTURBANCE OF SUCH INTER-RELATIONS

BY

John Phillips,

University of the Witwatersrand, Johannesburg.

Summary of an Extempore Address delivered 5 July, 1939.

Ecology is simply the study of life in relation to environment, hence the scope of such a study is extremely wide. In addition to being concerned with all forms of life, with many details of technique, and with the bearing of information won from many different fields of science and experience, ecology also embraces a point of view, a working philosophy. As interrelation, co-ordination and integration are fundamental in the ecological point of view, it is clear that such a view is *holistic*: it desires to see, to understand, to interpret *life as a whole*.

Certain basic relationships between life and the environment exist; these briefly are the *action* of the environment through its various elements, or factors, upon the living organism; the *response* or *reaction* of living organisms, this in itself inducing a definite, if at times almost imperceptible, change in the environment; the *co-action*, or competition and co-operation, that exists among living organisms. As life, then, is acted upon by environment, as environment is altered by life, and as various forms of life exist together as the ultimate outcome of stress, strain, fighting, conquest, victory, co-ordination and co-operation, it is clear that ecology has much physical, biological, and psychological material to study, and to serve as its inspiration.

It is evident from much that has been said by other contributors to this symposium that there are innumerable ecological facets of the grand, if depressing, subject we are discussing: *the need for the investigation and conservation of human resources in South Africa.* It will be appreciated that I cannot in the time at my disposal do more than focus certain high-lights.

I commence by mentioning some of the ecological problems inherent in the central issue with which we are dealing:—

South Africa has a striking but difficult *topography.* High altitude over a large portion of the country may indeed be having an effect through pressure and other relations. Linked with high altitude is a high incidence of radiation, particularly short-wave

radiation, which itself may be indeed the most potent factor facing human life at high altitudes. Portions of the country are at low levels—the so-called Low Veld being an example; heat and drought on the western side, heat and moisture on the eastern, produce their particular difficulties and problems.

Our *climate* is much boosted by novelists, tourist agencies, officials of the Government responsible for attracting visitors to our shores, and well-meaning but often ignorant patriots. There is so much that could be said regarding the demands made by our climate upon all forms of life, and upon forms not native to Africa in particular, that I must content myself with the generalisation that South Africa's uncertain, and in several respects *severe*, climate is one of our national problems, and not the wonderful asset we are accustomed to hearing and seeing exaggerated. Some of the conditions that present health, educational, agricultural and sociological problems are the widely spread *low humidity*, the great range in aerial *temperature* over the day and over the seasons, the local severity of *frosts*, the intensity and duration of *radiation*, high *evaporativity*, low or high—and *irregularly* low and high is the point—*rainfall;* hot dry *winds* frequently strongly *dust-bearing;* a lengthy "dry" season when crop production is severely limited and grazing and browse poor. Obviously such climatic controls have a direct and indirect action upon man and his practices.

When we turn to the *soils* of the country we find that they abound in types even as they fairly uniformly are poor. Lack of bases, of sufficient chemical foods readily available to plants, and of suitable physical characteristics fundamental to a successful husbandry, show their effects in the natural and in the introduced vegetation, and through these upon wild and domesticated stock. Man, in his dependence upon vegetation and lower animals, in turn suffers from malnutrition when he has to live too close to Nature and without the aid of foodstuffs containing adequate supplies of nutriment.

Our *vegetation* itself sets problems. There are very, very few *good* indigenous food plants; there are none of real economic importance when compared with such plants as the introduced maize, wheat, legumes, tubers and deciduous and other fruits. Our agricultural and pastoral crops give, on the whole, low yields per unit area, and have to bear the burden of heavy freight costs, even if such be borne in practice by the State. Without subsidy aids the production of many crops would be impossible. That such subsidies are granted by the State, or that protective Customs measures have been brought into action to bolster up the production of certain crops, are themselves a sure indication of the low level of productivity and production economics.

Then again, insect, fungus, bacteria, virus and other diseases take heavy toll of our plant crops, and mismanagement—and often this has amounted to *criminal maltreatment*—of our native

vegetation has been the first step in the ever quickening march of soil deterioration, erosion, and water loss.

Turning to the animal population of the Union, we find that we are facing great problems in regard to rodents, fleas and plague; termites in relation to destruction of grass, trees, and timbered buildings; locusts and widespread loss in crops and grazing; ticks as vectors of various diseases of domesticated animals; mosquitoes in their bearing upon the incidence and spread of malaria; the tsetse-fly as vector of animal trypanosomiasis or Nagana. Our domesticated stock not only suffer from many diseases, despite the splendid work down the years of Theiler and his successors at Onderstepoort, but also in all too large proportions are underfed, poorly housed, if housed at all—and our climate has its rigours both in summer and in winter—and frequently suffer from in-breeding. It is worth enquiring whether continued exposure of introduced animals to the direct and indirect influences of high solar radiation intensity may not in itself be responsible for degeneration in size and vigour; I understand that observations at Armoedtvlakte by certain veterinary officers are interesting in this connection, while the work of Dr. Quin upon the interrelation of light and the signs and symptoms of the disease in sheep associated with the common weed *Tribulus terrestis*, is suggestive.

When we look to the human population of this country, a population ranging widely in colour, culture, economic wellbeing, and—in the present matrix of politics and religous thought—hope in the future, and when we cast our eyes back over the pages of our history we cannot fail to be depressed by the complexity of our problem. That our problem of building up a State in which all men of all colour will be given an even chance, is insoluble provided there is no grand change in the outlook and the spirit of the European portion of the South African nation goes without saying. As a South African by several generations I must admit I do not see any really bright gleam of hope on the horizon, but I see rather the gathering darkness of cumulative obscurantism and sectarian religous intolerance. Our Bantu peoples are still over-congested in Reserves, despite attempts that have been made recently to relieve the land-poverty; there is still a movement from the reserve or tenant lot to the towns; in the towns there is the growing antagonism that comes from Natives being forced into competition for unskilled and semi-skilled labour with members of the Poor White class. Miscegenation—and this does continue through illicit intercourse between Bantu and the European although there has been for some years a special Immorality law aimed at preventing this—according to the studies of Advocate Findlay and other discerning observers, gives us furiously to think. Segregation is spoken of in our Parliament as a legislative aim of certain politicians. And above all is the ever-growing spirit of intolerance of the Native exhibited by so

large a section of our European population. Beyond this, however, is the failure to realise the dependence of this country and its European stock upon the Native; this is well brought out in a remark reported of General Sir Arthur Cunynghame, one-time General Officer commanding the British Forces in South Africa, who upon a tour of the country in 1879, said of diamond diggers at Kimberley, that it was important to know that in South Africa the term "digger" did not mean one who did any digging, but rather a European who stood watching Natives digging for him!

If our Natives present a growing economic problem to themselves and to the European, our Coloured people set us even more food for thought in respect of the future genetical make-up of our "European" races, and the attitude of our children and grand-children to "a touch of colour" in White stock, the psychological effect of "escape" upon lighter skinned people of Colour who manage to "escape" from Coloured circles to European, often through marriage or through transfer from one area of the country to another, is a matter worthy of the attention of students of sociological psychology; clearly the Mendelian after-affects in the national make-up may be profound and to those who are fastidious, profoundly disturbing.

Asiatic peoples who have come to our shores—sometimes because we ourselves have encouraged their coming by leaving *niches* in industry and trade where none but the most frugal dare make any attempt at establishment—on the whole have been a law-abiding, loyal and discreet section of the community. Some of these have shown considerable public spirit for good, and some have possessed rare ability. Against them as a whole we hear increasingly the cry that they have taken a root-hold where our stock should have been in possession; that they victimise the Poor White, and so forth Recent Bills in Parliament have not breathed the spirit of understanding, co-operation, and liberalism Our intolerance—following years of slackness and apathy in governmental, public and individual minds—presents one of the most difficult and delicate problems facing us and those to follow. It is worth our while to enquire whether a reply to the statement that Asiatics have driven out Europeans, for example, from trading occupations in country districts, and that because only their ability to exist at a lower standard of living, is not rather that these people have in addition shown considerable efficiency and much perseverance and determination.

I touch now upon a matter of the greatest delicacy: that of two strong White races in the same country. Both the British and the Dutch stock in this country have sprung from peoples of great strength of character and with deeply rooted national culture and tradition. This in itself is a psychological difficulty: it does no good to clothe the fact in raiment of equivocation . . .

We certainly should have had a less turbulent history, we certainly should be more assured of a less stormy future, had we had one major White race in South Africa and not two. Progress has been slowed, and progress will continue to be slowed by reason of the inevitable compromise that must be sought in all matters likely to disturb the sentiments of one or other race. Canada has had her difficulties, and has them still, if to a lesser degree in proportion than the Union. Australia, on the other hand, has escaped racial problems, European as well as Native, and her course accordingly has been, and will continue to be, clearer than our own. But I do not believe that great as our problem is, that it is insoluble. Speaking as a mere Sassenach, I believe that Scotland has shown us the way. Scotland is peopled by a stern, hardy, proud race steeped deep in an ancient culture. England was her traditional enemy for centuries; she bled sorely as the result of her feuds with her stronger neighbour. Yet to-day we see the Scots in whole-hearted union with England; in spirit as well as in the material sense. Scotland has united with England to form a greater nation. But the point of importance for us is that Scotland has lost nothing of her national pride, her national culture, she holds to her national garb, she is as proud of her Scottish regiments—and these are second to none in the British Army and in the World—as is England; she has *sublimated a smaller nationalism in a greater one*, and in so doing has emerged greater.

Finally, a great problem for South Africa to face is that of *isolation*. Isolation has played a great part in moulding some of the best in our heritage; isolation, at the same time, has been parent of narrowness and shortness of vision, of self-satisfaction and self-sufficiency; isolation has been responsible for our intellectual wilderness. An absence of sufficient stimulus, and resultant stagnation, satisfaction with things as they are, and mental lassitude are interlinked, and well may have a generally deteriorating influence as time goes on. We lack sufficient fresh blood of the most desirable type; *genetical inbreeding* actually is taking place in some areas; *mental inbreeding* is taking place on a very much wider sphere.

Perhaps I have added even further to the feeling of depression that the contributions of previous speakers have brought about in you; I confess I have not said anything very encouraging so far! I believe, however, that something could be done to adjust man better to his complex environment of difficult topographical, climatic, soil, biological, human and other interrelations. I mention in summary fashion some of the steps that I believe would lead nearer a solution of some of our problems:—

(1) We should undertake a really up-to-date, dynamic survey of our climatic features, and should attempt to relate these to our soils, vegetation, and biological and other problems. Bio-climatology should be the subject of liberal Government

support, and our Universities should pay far more attention to this than they have up to the present. Probably one of the more important subjects requiring physical, biological, agricultural, and clinical study is that of intensity and quality of radiation.

(2) I have stressed before this Association on two previous occasions the need for a progressive ecological-economic survey, in relation to soil, vegetation, production and other features of the problem of maladjusted agriculture. I believe the information to be obtained by such a survey is essential to any sound agricultural policy; without such information our policy must be fortuitous and extemporising from period to period.

(3) Our soil, veld and water conservation policies and practices must be supported more by the Government and the farming community; we must spend less money on spectacular irrigation dams and schemes, and more upon soil and vegetation conservation and improvement.

(4) State appropriation of submarginal agricultural-pastoral areas must be faced, in spite of criticism that this is playing to the tune of dictatorship; State-control, and perhaps State guided agricultural pastoral management are sorely wanted.

(5) We require a far more enlightened education policy and practice—and this refers to secondary, primary and university education. We have not yet learned, as a nation, that teaching and learning are not identical, and that knowledge and wisdom are poles apart. We have not yet learned how to provide the best conditions for the development of the intellect; we have been too much occupied with the discipline of "teaching" methods. Service and learning are linked; this, again, we have been slow to appreciate in our universities.

(6) We have undertaken social work and sociological studies, but I am still unconvinced that these have been sufficiently realistic, and that these have aimed sufficiently consistently at the study and the treatment of *fundamental causes* in social and economic problems in both rural and urban areas. There is still a great opportunity for sociologists and social workers with the right spirit, the right viewpoint, and the right technique, to do fine work in "platteland" and city slum alike.

(7) A State-medical service is long overdue; this subject has been debated so eloquently by those far more capable than myself that I venture no further remark than this: if we do not dare face a State-medical service for the whole population, we should in the interests of humanity and in the narrower interests of the European section of the community, grant better medical facilities to our Native and Coloured peoples.

(8) Birth-control clinics are required in greater number; while the few there are in the country are functioning satisfactorily considering their meagre funds, many more are wanted, particularly in areas where they can be readily available to

indigent classes rural and urban alike. The better educated class is practising control, but for the greater part the poorer classes are not, hence there is likely to be an ultimate maladjustment of numbers of offspring from the professional and middle classes in relation to the offspring from the poorer classes.

(9) Apathy in political matters on the part of persons best qualified to represent the country in Parliament results in unsatisfactory elements—or at least elements that are not as efficient as they should be—forming too great a proportion of our governing bodies, civic, provincial and national. Our best educated people, our leaders in industry, commerce and general business, our very best farmers—these groups are insufficiently attracted to politics. Partly this is due to apathy on the part of the groups concerned, but there is a lot of truth in the saying that a country gets the government it deserves. Constituencies are to blame for not more seriously attempting to get the best possible representatives. If there be financial reasons against particularly good men or women being prepared to take risks inherent in a political career, then arrangements should be made whereby political parties or other groups undertake to protect the interests of the person they consider really worthy of election. At present we tend to be ruled by too many of those who drift into politics, and not enough by those who definitely would have the ability and a flair for matters legislative.

In conclusion I make another appeal to men and women and Science in South Africa. Let the cool, discriminating spirit of Science, eternally in search for Truth as we understand Truth, inspire all of us who follow the discipline of Science, let this spirit draw together men and women of different races and traditions, of different political groups and ideas, to work together for Truth, for Unity, and for Progress. Let us rise above our racial culture to produce a sublimated South African culture, that our country may have gilded on the rolls of world achievement her fair name.

Let us exert such an effort for understanding and unity in this Association for the Advancement of Science. *Noblesse oblige.*

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(9)—SUMMARY OF MAIN CONCLUSIONS

BY

The Hon. J. H. Hofmeyr, M.P.

Delivered 5 July, 1939.

I must commence with a word of thanks. We are, of course, most grateful to all the speakers, but we owe in addition a particular debt of gratitude to Dr. Malherbe and Prof. Phillips for what they have done in organising this symposium, which has been an undoubted success.

Such a symposium presents a healthy reaction to compartmentalism in science. There are no watertight compartments in life; there should be none in science. On the contrary, there is an essential unity of knowledge, and, as Prof. Maingard pointed out last year, the ultimate aim of all science is the study of man.

This symposium has also illustrated the importance of team-work. If truths are to be put across effectively to the public, team-work is the most necessary agent thereto.

It is appropriate that at a gathering like this several speakers should have laid emphasis on the importance of insisting on facts—on the necessity of a clear and dispassionate search for the truth. Dr. Grosskopf has stressed the point that patient research, clear thinking and courageous action are needed. Dr. van Rensburg has emphasised the importance of getting at the facts as the basis of our educational policies. In that connection, I cannot help referring to the valuable work which is being done by the Bureau of Educational and Social Research, over which Dr. Malherbe has so ably presided. While we congratulate him on his appointment as Director of Census, we regret very sincerely that this must mean the cessation, wholly or in part, of his association with the Bureau.

The starting point of our discussions to-day has been the excellence of the human material which we have in South Africa. On the European side we believe, and I think we have justification for believing, that we are descended from some of the best stocks in Europe. In the Bantu we have one of the outstanding non-European stocks in the world; of that its survival under the pressure of influences introduced by the entry into South Africa of Europeans is a proof. It proves also that, despite what is sometimes said in other countries, there has been an essential humanity of outlook on the part of the European towards the

non-European in this country. Dr. Grosskopf rightly emphasised the beneficial effects which the European has exercised on native life, but that in no way detracts from our acknowledgment of the fact that the Bantu stock, in order to have survived as it has done, is essentially virile.

It has been shown, further, that this excellent human material is in danger of deterioration. There is deterioration on the physical side As far as the Europeans are concerned, Dr. Cluver has shown that there is a lessening production of human life. The European people of South Africa are, if not less healthy than they were a generation ago, not very obviously more healthy. South Africa is lagging behind other countries in raising the standards of health, and that in itself is degeneration. When we come to the non-Europeans, there is a very definite and observable decline in health and physical vigour. That is a most important fact in South Africa's economy. By and large, then, the position on the physical side is very far from satisfactory.

On the moral side it is not so easy to come to a conclusion. In dealing with moral issues one is always apt to base conclusions on impressions rather than on facts, and to be influenced by the tendency to extol the virtues of past generations. Mr. Graham Bain has, however, given us facts in regard to the increase in juvenile delinquency in South Africa, both on the European side and on the non-European side. At that very important Conference on Juvenile Delinquency which was held in Johannesburg last October some very disturbing facts were forthcoming in regard to the native aspect of the matter. Undoubtedly our failing to cope sufficiently with native educational needs, especially in the towns, is wreaking its nemesis on us in an increase in native juvenile delinquency, which means an increase in native adult crime.

There is one aspect of the matter which interests me very considerably. I am thinking of the effects from a moral point of view on the Afrikaans-speaking section of the community, of it becoming as it is so largely becoming to-day an urban instead of a rural community. In very large numbers Afrikaans-speaking people have in this last generation moved from the farms to the towns, and there they are confronted with the necessity of adapting themselves to a new environment. It is a very important question from the point of view of the moral welfare of the nation, whether they are standing up to the stresses and strains of urban life. There are some indications that they are not adequately adapting themselves to these stresses and strains. There are some signs at least of a moral decline in the urban Afrikaans-speaking population. I believe, however, that it is too early to pronounce final judgment on that matter. The process of adaptation is still only in its early stages. One thing in any case is clear, and that is that these

same Afrikaans-speaking people from the farms are adjusting themselves very efficiently to the needs of the industrial employment in which to-day they are being absorbed. On the mines of the Witwatersrand Afrikaans-speaking miners are proving to be as good at their job as the Cornish miners ever were. Moreover, industrialists tell us that the Afrikaans-speaking worker in industry has for the most part proved that he has a natural aptitude for such occupations. I believe that a solution of the problem of the effects of rural poverty, which is the real kernel of poor whiteism, is going to be found to a large extent in the conversion into industrial workers of those who have not been able in the past to make a living on the land.

We must then conclude that South Africa has had most excellent human material to start with, but that, after making all due allowances for the necessity of caution and conservatism in drawing rash inferences, that human material is showing some signs of deterioration.

If we are asked to assign the root cause of that deterioration, I think we can give only one answer—that root cause is poverty. Some of the speakers who contributed to the prearranged programme emphasised that point directly or by implication, others made it in the course of discussion. Mr. Justice Krause in particular stressed it effectively and forcibly.

We have suffered a good deal in South Africa from the doctrine that this is a rich country. In that regard the mining industry, great though its services to South Africa have been, has actually done us a disservice. We have an immensely rich gold mining industry. Because of that we have come to believe that the country as a whole is rich, with the result that there has been built up in South Afrcia a higher standard of living than the permanent resources of the country really warrant. I believe that it is a very serious question in South Africa whether we are not demanding a higher standard of living than the natural conditions of our country justify. I believe that it was correctly suggested this morning that that demand on our part is producing a certain disharmony for which we are paying, and will continue to pay, a very heavy price. The truth is, of course, that this is a rich country from the mineral point of view, but that from the agricultural point of view it is very far from being a rich country. You will remember the emphasis which Dr. Phillips laid on the poorness of our soils. If you take our average national income and divide it by the population which has to be fed and clothed out of that income, you will realise what an essentially poor country South Africa really is. Indeed, I would be almost prepared to say that on to-day's facts South Africa is a desperately poor country. Because of that essential poverty of the Union, social workers are fighting, as Prof. Batson reminded us, a losing battle, since those sub-

standard conditions against which they are fighting are not so much exceptional as typical of conditions in this land of ours.

Poverty then is the main cause of our physical ills in South Africa. If you study Dr. Cluver's paper, you will see to how large an extent the evils of which he spoke are caused by such factors as bad housing and malnutrition. Poverty is also the main cause of our moral ills. Mr. Graham Bain rightly emphasised that when speaking of juvenile delinquency. For my part, I regard poverty as the cause and not the consequence of our moral ills, and I think, therefore, that Prof. Batson was right in his reference to the Carnegie Commission. Dr. Boehmke suggested that bad physical habits might be the cause of poverty. I do not think he goes far enough. It is poverty which is the primary disorder in the body politic and in the body economic. A similar question sometimes arises in regard to housing policy. Do slum-minded people create slums, or do slums create slum-minded people? I think experience proves, especially the experience of new housing schemes in the Union, that most of the people who live in slums are not slum-minded people. Ninety per cent. of these people are capable, if given decent housing, of being converted into decent inhabitants of decent houses. Moral evils are not the primary cause of poverty. To a far larger extent they are the consequences of poverty. We must therefore agree with Prof. Batson that social work is not merely a narcotic, but that it can and should become a stimulant.

There is a danger of our being influenced in South Africa by the idea that the growing expansion of social services by the State will destroy the independence of our citizens. Of course, it is important that our people should retain their independence of mind and spirit, but this fear that expanding social services will rob our people of their independence sometimes expresses itself in a statement such as this: "Let them continue to wallow and struggle in poverty, but don't take away their independence." The danger, to my mind, lies not in doing too much in the way of social services, but in doing it in the wrong way. It is the direction of our social work that is the most important factor.

Let us come back to this basic fact of poverty. Poverty is a primary consequence of economic facts. I agree with Dr. Grosskopf that there is no sudden and miraculous panacea for economic evils. Prof. Phillips has suggested certain drastic reforms, but they would take a long time to bring about. There are very grave difficulties to be faced in any attempt to get rid of poverty by means of great social changes. Of course, I do not accept the fatalism sometimes implied in the quotation of the saying that "the poor ye have always with you," but I do realise the difficulties in the way of revolutionary economic changes, and I am very conscious of the fact that in the meantime we have to deal with the consequences of poverty. The

measures which we are taking may be called "palliatives," but they are no less necessary on that account. Let us review some of these measures.

The importance of physical education has been stressed, and rightly so.

Then, too, we have heard a good deal during the day of the importance of social services from the point of view of their stimulative and rehabilitative aspects. Generally, education for the stimulation of right habits is a most valuable factor.

Then there is the much larger question of housing. To-day we are paying a heavy price for the slums we have allowed to grow up in our towns from the point of view both of physical degeneration and of moral decline. In recent years an attempt has been made to attack this problem, and large sums of money have been made available for housing schemes, but much more is needed. Unfortunately, there has been a check in the provision of funds for further commitments for housing schemes this year, as a result of the necessity of limited capital expenditure on other matters in view of the increased expenditure on defence. That expenditure on defence is necessary, but it is bringing us in South Africa up against the "guns or butter" problem; with us it is "guns or housing."

Then there is the problem of malnutrition. Dr. Cluver has emphasised that malnutrition results in a high infant mortality rate and in the weakness of those who survive. It is not the case of the "survival of the fittest," but of those who survive being rendered less fit. When malnutrition was discussed in Parliament, those who spoke about it for the most part appeared to think of it only in relation to Europeans and not in relation to the non-Europeans, but malnutrition among the natives is, if we take the long view and regard the economic aspect of the matter, much the graver problem of the two. Some years ago the Chamber of Mines woke up to the importance of this matter in regard to the question of native labour on the mines and started some important investigations in the Ciskeian area. In this connection there is also to be considered the tremendous increase which is taking place in the expense of providing hospital services for natives. Much of that money might have been better spent along the lines implied in the realisation that "prevention is better than treatment."

This problem of malnutrition amongst the natives has a rural aspect and an urban aspect. There are the natives in the reserves, in which connection Dr. Grosskopf has stressed the importance of better use being made of the land possessed by them. Dr. Phillips has mentioned what is being done to buy more land for native settlement, but the mere buying of land is not enough. The native has to be taught to use his land to the best advantage, so that he can produce more crops and crops of the right kind. Undoubtedly there has been much improve-

ment in native agriculture of late. We have begun to tackle the problem of native agriculture, but even so, there have in the last ten years or so been signs of decline indicated by the fact that the native reserves are importing more foodstuffs than they used to. We have obviously still got a good deal to do along the lines of the better use of the land resources of the native territories.

Then there is the urban native position. There has been a tremendous increase in the number of native females settling permanently in the towns. The last census figures reveal that there are to-day more than 400,000 native females in the urban areas of the Union. That, I think, indicates the extent to which the natives have found in the towns of the Europeans a settled home. But native urban wages in relation to native subsistence needs are low, largely for traditional reasons. In the old days the native came to work in the towns from the reserves where he had his home. He had a marginal subsistence in the reserves, and he only came to the towns to get some additional income to pay taxes and to buy things which he otherwise could not buy; but he was not dependent in the first instance on the wages he earned. To-day, however, he is, to an increasing extent, dependent on these wages, and these wages, fixed as they were in the days when the natives had other sources of income, are inadequate to the conditions of to-day where the whole family is living in the urban area and has no other resources to draw from. Another depressing feature in relation to native urban wages has been the tradition in this connection of the gold mining industry. That industry is essentially a low-grade industry. We have been told that the industry cannot be kept going without a supply of cheap native labour. We have been told also that native wages on the mines cannot be increased because some of the mines would go under if that were done. The real wages of the natives on the mines are to-day less than they were in 1914. In recent years the conditions of service of the European workers on the mines have been improved very substantially. There has been virtually no improvement as far as the natives are concerned. I have indicated the reasons usually advanced for that fact, but I cannot help feeling that the justification has now begun to disappear. Not so long ago Sir Robert Kotzé drew attention to the fact that while in 1930 the average tonnage milled per native labourer on the mines for the year was 158, in 1937 it had risen to 177. In other words, as a result of improved methods of organisation there has been an increase in productivity of 12 per cent. per native labourer. Surely the native should have had some benefit from that increased productivity? The shareholder and the European worker have had benefits, but the native has had none. In this connection I could not help being interested by the very important reference made by Dr. Jokl this morning to researches which are taking place in regard to resistance to heat in the

mines, which, if successful, would make it possible for a much smaller number of natives to do the same amount of work. That would also mean increased productivity of the native labourer. Surely that must bring with it the necessity for increased native wages? Certainly, from the point of view of the general economic structure of South Africa, the raising of native wages in the towns is something very necessary and overdue.

Another point that has been made to-day has been with regard to the better distribution of the products of the land, if only in order to make the protective foods more readily available. I cannot help saying that I am coming more and more to the conclusion that, whatever may be the cost, we shall have to find the means in South Africa of retaining protective foods in this country which are now being exported.

A related question is that of the application of the maize levy to the Transkei. There we have more than a million and a quarter natives, to a large extent dependent for their very life on a cheap supply of maize. The policy of making the consumer pay 4s. a bag by way of levy was obviously one which had been embarked upon without due regard to the essential needs of those native people.

There is also the wider question of the integration of the Bantu into our economic structure. There, I agree with Dr. Grosskopf that there need be no essential disharmony of interests between European and Bantu in this country. I am glad that he urged so courageously, that instead of excluding the native from certain avenues of employment for the sake of the white man, we must face the necessity of devising an industrial system in which both can be organically absorbed.

I have been speaking so far of the physical aspect of the matter. It was with that aspect that we started, but we did not stop there; we went on to deal with the moral and intellectual aspects.

On the intellectual side there is the vast question raised by what Dr. van Rensburg said—whether we are doing the best we can to develop the intellectual resources of our nation. We have had one Education Commission after another; usually they have led to very little in the way of result. I am one of those who believe that there is not so much wrong with our educational system as some people think. The essential line of progress which we should be preparing to follow is that of the better organisation of facilities for post-primary education. I use that term in a wide sense, for I regard education as meaning more than mere schooling. It certainly includes employment taken in conjunction with such part-time instructional facilities as may be feasible. It is the problem of the adolescent which is the chief unsolved educational problem of to-day. It has two aspects—the provision of the necessary facilities, and the sorting

of the pupils into those facilities. Especially in this latter connection Dr. van Rensburg had much of value to say to us.

Before I leave this point, may I just refer to the fact that Southern Rhodesia is progressing more rapidly than the Union in its approach to the solution of this problem, but, of course, it is favoured by the fact that it has less deep-seated traditions to fight against.

And then I come to the moral aspect. In this connection we were concerned mostly with what Mr. Graham Bain told us about juvenile delinquency. There were two outstanding notes in his contribution; they were also the two outstanding notes sounded by Dr. Cluver. That shows, I think, how closely the physical and moral aspects of this question are linked up.

The first of these notes is that prevention is better than treatment. It is true in regard to the building up and maintenance of a healthy nation that it is better and cheaper to prevent the development of physical or moral ill-health than to treat it afterwards. It is certainly better, not only from the human, but also from the economic aspect.

The other outstanding note of Mr. Bain's contribution was that he also came back to the point which was fundamental to Dr. Cluver's paper, that poverty is one of the main causes of our ills. I do not say it is the only cause; I accept what Dr. Bush said as to the importance of heredity, but it is none the less the cause in most cases. Mr. Bain indicated the importance of poverty in relation to juvenile delinquency. As every social worker knows, the causes of juvenile delinquency are essentially the same as the causes of juvenile destitution, and the best way to prevent juvenile delinquency is by seeking to remove the causes of juvenile destitution—these things were fundamental to the Children's Act of 1937. That Act has generally been accepted as a piece of legislation which puts South Africa among the leading countries in this particular field. What are the principles underlying it as far as juvenile delinquency is concerned? The first is that prevention is better than treatment. The second is that treatment in a normal family is better than treatment in an institution. There is, of course, an inescapable necessity for institutions, but wherever possible, it is our policy to-day, by means of mothers' pensions or in other ways, to maintain or where necessary to create the family life, so as to keep the children out of institutions. The third principle is that the treatment of the child has to be adapted specially to the needs of the individual, and, with that end in view, through the machinery of reformatories, hostels and the probation system, it is sought to make it possible for the juvenile delinquent to serve a gradual apprenticeship to life in society, so that he may become a normal and decent citizen.

I have now surveyed the ground which we have covered to-day. We have passed from the physical to the moral and

intellectual aspects of the question. Have we gone far enough? Someone asked the question: "For what purpose do we want to conserve our human resources?" Does that not suggest that there is another aspect of the matter—a spiritual aspect? On that Mr. Graham Bain and also Dr. Phillips touched. May I put this question: Is there not also in South Africa in regard to our human material a deterioration on the spiritual side as well as in respect of physical, moral and intellectual standards? I use that word "spiritual" in a wide sense. In so far as the activities of the Church fall within its scope—and that is important from the point of view of Europeans and coloureds, as well as, to some extent, of natives—I am afraid that we have to admit that the Church is losing its hold in South Africa But the word also covers the spiritual value of tribal tradition and tribal loyalty amongst the natives, which was once so prominent a feature of their life. That tradition and that loyalty are going, and, try as we may, we cannot succeed in restoring them.

I hope you will not take it amiss if I conclude this symposium by bringing you back to what I believe to be a fact which underlies the words of St Augustine. "Oh God! Thou hast made us for Thyself, and our hearts are restless until they find rest in Thee." The truth is that in every human being endowed with personality there is an element which needs something more than physical or intellectual satisfaction—and that element in man requires a spiritual satisfaction. Because I believe that to be true, I also believe that without some spiritual revolution—and I use those words in the very widest sense—we cannot hope to make as much of our human resources in South Africa as we could and should.

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